The Canadian Entomologist

Vol. LXXXVI Ottawa, Canada, February 1954 No. 2

The Effect of Needle Structure upon the Susceptibility of Hosts to the Pine Needle Miner (*Exoteleia pinifoliella* (Chamb.)) (Lepidoptera: Gelechiidae)

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Introduction

The pine needle miner (*Exoteleia pinifoliella* (Chamb.)) is one of at least seven pine needle miners occurring in North America. A native to the East, it is widely distributed from Southern Ontario (6) through the Atlantic States to Georgia (1).

The insect is a persistent and annoying pest that infests forest trees of all ages from nursery transplant beds to mature stands. The moths oviposit year after year on the same trees causing localized infestations; one part of a stand may be heavily populated, while an adjacent area may remain untouched for years.

The species has never been reported as a serious pest. It is probably seldom responsible for the killing of forest trees growing under natural conditions; but it is not unusual for the insect to cause browning of the foliage over large tracts of forest land.

On plantation trees and ornamentals, however, the insect is much more significant; for it not only renders the trees unsightly, but is capable of killing them.

Several species of thick-needled pines serve as suitable hosts. There was found to be a relationship between their susceptibility to mining and the internal structure of the needle. Studies were made on plantation trees at the State University of New York, College of Forestry Experimental Station, Syracuse, New York.

Host Trees

Of the trees indigenous to the North, records and observations indicate that jack pine (*Pinus banksiana* Lamb.) and pitch pine (*P. rigida* Mill.) are favored hosts. The red pine (*P. resinosa* Ait.) is also attacked but no indication of heavy infestation has been observed.

In the more southerly part of the insect's range, other hosts have been recorded (1), but their relative susceptibility is not known. They include the scrub pine (*P. virginiana* Mill.), shortleaf pine (*P. echinata* Mill.) and long-leaf (*P. palustris* Mill.). The table mountain pine (*P. pungens* Lamb.), planted in Syracuse, New York, was noticeably fed upon.

In addition, two western pines, ponderosa pine (*P. ponderosa* Dougl.) and more especially lodgepole pine (*P. contorta* Dougl.), may become subject to attack when planted within the insect's range.

A considerable degree of immunity, on the other hand, exists in the case of Scotch pine (*P. sylvestris* L.), even if the branches are interlocking with infested foliage of other species.

Needle Structure

Resin canals are present in the needles of all pine species, but are occasionally absent in individual needles. The number varies according to the species but is far from constant in any one, excepting in a few where the normal number of

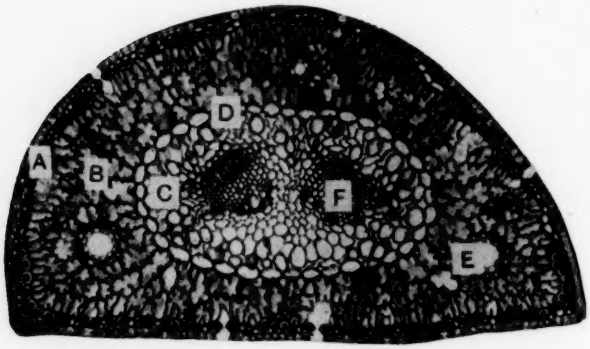

Fig. 1. Transverse section of typical pine needle: A, dermal region; B, mesophyll; C, stelar region; D, endodermis; E, resin canal (medial); F, fibrovascular bundle.
(Photo by W. M. Harlow).

canals is two or three. Large vigorous needles occurring in the open sometimes show many more canals than those, even on the same tree, located in the shade (2). The position of the canals (Fig. 1) differs with the species, some being external, in close contact with the dermal region; some medial, situated in a central position in the mesophyll; and others internal, closely placed against the endodermal cells.

Mining Habits of the Larva

In the vicinity of Syracuse, New York, moths appear in early June and lay eggs singly beneath the bark scales of twigs.

The newly-hatched larva enters the current year's needle on the flat (or ventral) side near the base where a small hole is made close to the mid-line. After mining a short distance, the larva cuts upwards to the mesophyll on the convex (or dorsal) side and feeds towards the tip. A broad, shallow mine is eventually formed between the two corner canals. In late summer, the damaged needle becomes brown and dry, and the larva returns to the basal area to feed within the unmined green tissue. Molting to the second instar takes place within the mine.

During September, the larvae abandon the dead needles and invade others of both the old and current year's growth. Entrance is typically made on the ventral side approximately ½ in. from the apex. Mining proceeds through the dorsal mesophyll towards the tip; and the larva molts to the third instar. The entire tip is then hollowed out. Early migrating larvae may destroy the tips of two needles during this period. The entrance hole is eventually covered with silk, the larva molts again, and hibernates in the fourth instar.

With the first mild days in March, feeding activity is resumed. About half of the larvae tunnel downwards from the overwintering mines, extending them about an inch and destroying most of the internal tissue. Other larvae leave to attack other needles approximately 1 in. from the tip, and mine apically, completely hollowing out the area.

In late April and early May, larvae molt to the final instar and migrate to enter another needle. A hole is usually made on the ventral surface about 1¼ in. from the tip and the needle is excavated as before. To facilitate emergence of the moth, the hole is enlarged to extend across the width of the needle. The

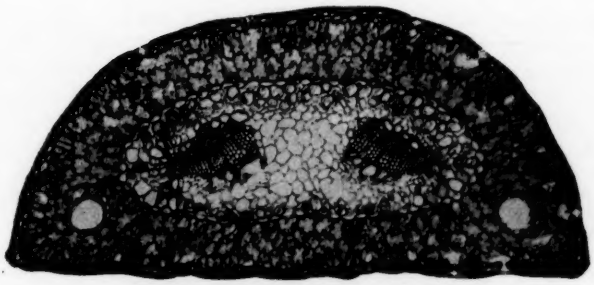

Fig. 2. Transverse section of needle of lodgepole pine (*Pinus contorta* Dougl.). (Photo by W. M. Harlow).

sticky sides of the mine as well as the opening at the surface are covered with silk. In early May, pupation takes place within the silken tunnel. A sharp spine on the pupal frons adheres to the head of the moth and slits the silk across the opening, thus permitting escape.

Observations

(a) *Lodgepole pine*: This western species was the most heavily infested of the trees under study. Approximately 500 saplings were so severely damaged and weakened that they had to be destroyed, and some were killed outright.

The resin canals in all needles examined were medial and two in number (Fig. 2), one in each corner.

(b) *Jack pine*: Planted jack pine was found to be the next most susceptible to attack. Trees from small to large size were heavily infested, but no severe after-effects or mortality resulted.

Although the needles were shorter and slightly narrower than in the lodgepole pine, the general needle structure and arrangement of the canals were similar.

(c) *Table mountain pine*: A single 10-foot tree surrounded by infested jack pine of the same size was well infested.

Typically, the resin canals are two to seven in number, the two in the corners medial, the others medial or both medial and external (2). Many needles were examined but never more than two medial corner canals were found.

(d) *Ponderosa pine*: Introduced from the West, this species was noticeably mined but never severely injured. Some trees appeared to be practically untouched, while others, obviously growing under poor site conditions, were almost as heavily mined as the jack pine.

Typically (fig. 3), the resin canals are medial, commonly 2, but occasionally 3 to 10 in number (2). An examination of infested needles, as well as needles from trees that were scarcely touched by the insect, showed that there were two canals only, one in each corner. These canals were very large, however.

(e) *Pitch pine*: Judging from the present literature, pitch pine is probably the natural host of the insect in the more northerly part of its range, (1, 3, 4, 5). Unfortunately, this species was scarce locally and the few trees observed were isolated and free from attack by the insect.

Typically, the resin canals are medial and internal, 2 to 11 in number. The resin canal in each corner is medial, and those in the dorsal area are usually few and internal (2). Needles examined from this locality had one medial canal in

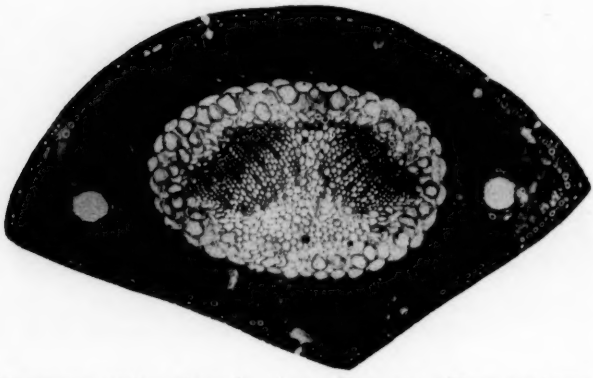

Fig. 3. Transverse section of needle of ponderosa pine (*Pinus ponderosa* Dougl.). (Photo by W. M. Harlow).

each corner with sometimes a third internal or medial canal in the ventral mesophyll. The canals were very small.

(f) *Red pine*: This species is definitely not a very susceptible host. Mining was found to be very light and only trees closely associated with heavily-infested species were attacked.

Generally there are two external ventral canals present (fig. 4): and in addition, one to four dorsal canals may occur either externally or medially, or both (2). In the infested needles examined, only two ventral external canals were present, but they were very large.

Red pine needles are quite slender, but pupae were found within the mines. In such cases, the needle walls were cleanly mined by the last-instar larva, and no resin canals remained. In other needles, however, where partly-grown larvae were active, the large ventral canals were left untouched, forming two longitudinal ridges along the floor of the mine.

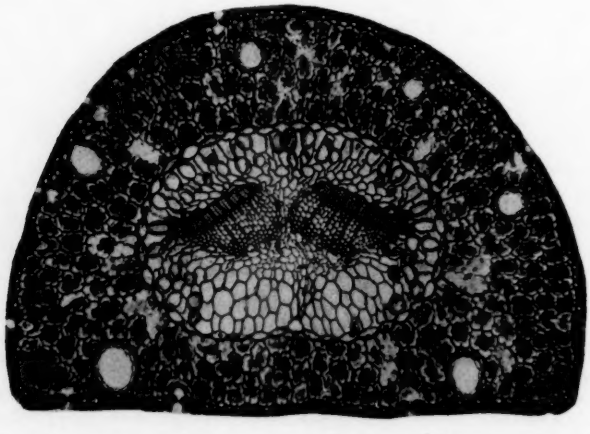

Fig. 4. Transverse section of needle of red pine (*Pinus resinosa* Ait.). (Photo by W. M. Harlow).

(g) *Scotch pine*: Trees grown from seed of Swedish origin were scattered through several of the infested plantations. Although the branches of Scotch pine were interlocked with mined foliage of other species, very few injured needles were found. Apparently oviposition had taken place to a slight extent, and while first-instar larvae had occasionally entered needle bases, apparently none had survived. Needle tips partly mined by migrants from other species, were occasionally found, but they were either vacant or occupied by dead larvae. Hundreds of needles from different trees were examined, but not a single pupa was found.

Needles of 10-year old Scotch pine scattered through the severely damaged lodgepole plantation were found to contain 6 to 10 resin canals. They were arranged one to three along the ventral side, one in each corner, and the remainder close to the dermal region on the dorsal side (Fig. 5). Usually infested needles were not hollowed out as in the more susceptible hosts, but rather contained an

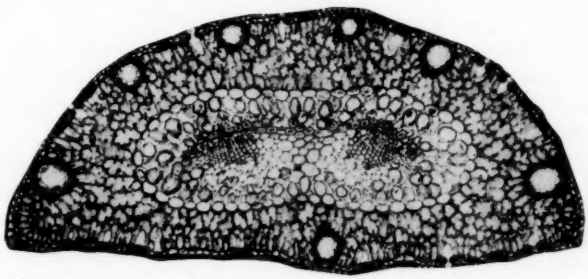

Fig. 5. Transverse section of needle of Scotch pine (*Pinus sylvestris* L.). (Photo by W. M. Harlow).

irregular tunnel in the central or stelar region. In a few cases. where dead larvae were present, the dorsal-dermal region, including the resin canals, had been partly mined.

Entrance holes started by last-instar larvae were common, but were never completed. One such needle contained three canals along the flat side where entrance had been unsuccessfully attempted.

In a 26-year old plantation of severely mined jack pine, mixed Scotch pine of the same size showed even less attack than in the 10-year old plantation. Rarely were the needle tips mined and unsuccessful attempts at entry were common. The canals were usually 12 to 16 in number and arranged externally around the mesophyll. Some oviposition had taken place, and first-instar larvae had successfully entered and cut out dorsal mines. The canals had been avoided, however, and remained as ridges along the wall of the mine. Not one larva had survived to leave the needle. Last-instar larvae migrating from jack pine had unsuccessfully tried to enter the needles. Black rings of hard resin remained as evidence, and upon four occasions a larval head was found imbedded in the resin.

Conclusions

There is a correlation between the internal structure of a pine needle and its susceptibility to injury by the pine needle miner. This is affected by the number, position and size of the resin canals within the needle; and possibly by the vigor of the tree.

In the plantations under study, lodgepole pine and jack pine were most favored by the insect. Only two moderate-sized resin canals were present and situated one in each corner of the needle. Larvae of all instars were able to feed with little, if any, interference from resin flow.

Table mountain pine was less favored, and while only two canals were present in the needles examined, two to seven were typical for the species.

Ponderosa pine ranked next in susceptibility, and although needle structure was similar to that of the more preferred hosts, the canals were very large and no doubt offered some resistance to normal mining activity. The fact that trees growing under poor site conditions were more severely damaged than others, indicates a possible association with the intensity of resin flow.

Pitch pine is considered to be a common host, but scarcity of this species prevented comparative studies. Three to four canals were present but they were very small and should interfere but little with insect feeding.

Needles of red pine were only slightly infested and provided some evidence of host resistance. Two large canals were located ventrally in such a manner as to impede larval entrance. Last-instar larvae destroyed the canals, but young larvae avoided them, leaving two longitudinal ridges along the floor of the mine. It was apparent that the large canals interfered with the normal mining habits of the younger larvae.

Scotch pine was definitely undesirable as a host tree. The conspicuous resin canals varied from 6 to 16 in the different needles, and the higher the number, the greater the resistance to the insect. There were many indications of feeding difficulties and mortality that were directly attributed to copious resin flow. The comparatively large and numerous canals played an important part in rendering needles unsuitable to the insect.

Acknowledgment

The information on needle structure, the descriptions of typical needles and the photomicrographs have been taken from the work of Dr. W. M. Harlow (2) with his kind permission.

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(Received May 8, 1953)

New Records of Insects in Canada in 1952: a Review[1]

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The number of new records noted in the Canadian Insect Pest Survey in 1952 was somewhat larger than usual and these and others are brought together for convenient reference in this paper. Canadian sources of information include Survey reports submitted by officers of the Entomology and Forest Biology divisions, provincial entomologists, and other co-operators; *The Canadian Insect Pest Review*; *Annual Report of the Entomological Society of Ontario*; *The Canadian Entomologist*; *Annales de l'Acfas*; and *Proceedings of the Entomological Society of British Columbia*. A reference to the collection of the leafhopper *Erythroneura flammigera* (Geoffr.) on cherry in British Columbia was noted in *Science News Letter*, a United States publication, and details of the occurrence were obtained from H. H. Ross of the Illinois Natural History Survey.

Insects New to North America

This section includes records of insects that had not previously been known to occur or to be established in North America.

A European tortricid, *Cacoecia oporana* (L.), was reared by J. H. McLeod, Entomology Laboratory, Vancouver, B.C., from larvae found feeding on snowberry, *Symphoricarpos* sp., at Vancouver. A single male had been taken at light in Vancouver in 1937, and in 1950 two specimens had been taken on imported horse chestnut in a Toronto, Ont., nursery. In Europe and Asia it feeds on a wide range of plants, notably apple, pear, plum, quince, cherry, blackberry, and walnut. It is a rather serious pest of apple in England.

A flea beetle, *Psylliodes chrysocephala* (L.), was identified from larvae and pupae collected on rape on a farm at Topsail, near St. John's, Nfld., by H. A. Butler, Entomology Laboratory, St. John's, in 1950. The extent of the infestation is not yet known. In Europe, the species is a common pest of cruciferous crops, especially rape and cauliflower. Adults feed on the seed leaves of the young plants, and larvae tunnel in the stems of the plants and midribs of the leaves.

A severe infestation of a fly, *Musca autumnalis* Deg. [=*M. corvina* F.], which occurs commonly in Europe, was reported from Nova Scotia by M. E. Neary of the Nova Scotia Agricultural College, Truro (Vockeroth, 1953). The infestation occurred in the walls and interior of a church at Middleton, and was reported to have been present for at least three years; at times the flies appeared in tremendous numbers in the interior of the building. In a limited survey of the Annapolis Valley, by C. J. S. Fox, Field Crop Insect Section, Kentville, and V. R. Vickery, N.S. Agricultural College, the species was found in smaller numbers at Bridgetown, Lawrencetown, Victoria Vale, Margaretville, and intermediate points. The larvae develop in cow manure in the field. Adults feed on blood from wounds and on other surface exudations on mammals, but apparently do not puncture the skin. They hibernate in buildings in much the same manner as the cluster fly, *Pollenia rudis* (F.). As the latter is already of considerable importance as an indoor pest in many rural and suburban areas, any additional nuisance from hibernating adults of *M. autumnalis* may be of considerable economic importance.

The wood-infesting weevil *Pentarthrum huttoni* Woll. was recorded by officers of the Systematic Entomology Unit from specimens that had been found

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in flooring in Quebec City in 1934. It was recorded also from Quebec in 1952 by Buck (1952) and Warner (1952). The insect has been reported from England, Belgium, Holland, and France. It commonly infests flooring, but in Europe has been found also in the wood of chests and casks, and in England it was found in the undecayed portion of a cherry tree when it was sawn into lumber.

Adults of a small, black, lepidopterous insect, *Monopis ferruginella* Hbn., about the size of a clothes moth, were found in thousands in a dwelling in Vancouver, B.C., by G. J. Spencer of the University of British Columbia. It is found commonly in dwellings in Europe, where it feeds on fungi occurring in association with decaying vegetable matter. It may constitute a considerable nuisance, but is of minor economic importance.

The leafhopper *Erythroneura flammigera* (Geoffr.) was reported by H. H. Ross, Illinois Natural History Survey, Urbana, Ill., from several specimens that had been taken on cultivated cherry in Vancouver, B.C., in 1950. The insect occurs commonly on a variety of shrubs and trees in Europe. A closely related species is a vector of phloem necrosis of elm.

Another leafhopper, *Macropsis fuscula* (Zett.), was collected in considerable numbers on loganberry on Lulu Island, B.C., by N. V. Tonks of the Fruit Insect Section, Victoria. Raspberry growing nearby was not affected. This leafhopper, too, is common in Europe, feeding on wild and cultivated species of *Rubus*. Another species of the genus, *M. trimaculata* (Fitch), is a vector of the peach yellows virus.

Several specimens of the grasshopper *Roeseliana roeselii* (Hag.) were collected by J. R. Beaudry at Ville Saint-Laurent and Montreal, Que. (Urquhart and Beaudry, 1953). The species occurs commonly in Europe, where it is widely distributed, and is believed to have been brought to America by aircraft, as the specimens were collected near Montreal airports.

The tortricid *Cnephasia virgaureana* Tr., a European pest of shrubs, vegetables, and other low plants, was recorded from St. John's, Nfld., by T. N. Freeman of the Systematic Entomology Unit, Ottawa. This is the first known occurrence since 1916, when the species was collected in this area and erroneously named *Tortrix oleraceana* Gibs. The record suggests that the insect is established in the Province.

Insects New to Canada

This section includes records of insects not previously recorded or known to be established in Canada but known to occur elsewhere on the continent.

The grasshopper *Psinidia fenestralis* (Serv.) was recorded by Beaudry (1952) from one male specimen collected at Berthier, Que. The species occurs from Wisconsin eastward to the Atlantic coast in the United States, and inhabits sand dunes held by the American species of beach grass *Ammophila breviligulata* Fern.

The grasshopper *Scudderia septentrionalis* (Serv.) was recorded by Beaudry (1952) from two female specimens taken at Lachute, Que., in 1951. The species occurs from Wisconsin eastward to the Atlantic in the United States.

An infestation of the cucujid *Oryzaephilus mercator* (Fauv.), commonly called the merchant grain beetle, in an insect collection at Ottawa was reported by W. J. Brown of the Systematic Entomology Unit. Although this is the only known occurrence in Canada, the species is cosmopolitan. In the United States it has been recorded from various points, but its distribution and economic importance are not definitely known because of confusion with *Oryzaephilus surinamensis* (L.), from which it differs little in appearance and feeding habits.

A widespread infestation of the curculionid *Apion longirostre* Oliv. on hollyhock in the area about Chatham, Ont., was reported by H. B. Wressell of the Chatham laboratory; only a few plants were severely damaged. It was recorded previously on this continent in Georgia, U.S.A., in 1914 and 1922, and later from Ohio westward to Missouri, also in the United States. It has been abundant on hollyhock along the southern shore of Lake Erie in recent years. Since its distribution in Europe is restricted to the Mediterranean region, it is not expected to spread far northward in Canada.

Larvae of the brown-headed ash sawfly, *Tomostethus multicinctus* (Roh.), were found feeding on three ash trees in London, Ont., by R. E. Sampson of the London office of the Plant Protection Division. The record is apparently the first in Canada although the insect has been known to be present in eastern and central United States for some time. It is sometimes a serious defoliator of red ash and white ash, particularly when these varieties are grown as shade trees.

The plant bug *Lygus nigrosignatus* Kgt. was reported by A. R. Brooks of the Saskatoon laboratory as abundant on cultivated mustard in Alberta, from Coutts eastward to Clarinda. The insect was previously described from Washington and Idaho, U.S.A., where it was taken with other species on alfalfa, and was reported to cause injury to the fruit of peach.

An infestation of the larger yellow ant, *Acanthomyops interjectus* (Mayr), in a dwelling in Hamilton, Ont., was reported by C. D. F. Miller of the Systematic Entomology Unit, Ottawa. The species normally nests outdoors, but occasionally becomes established in building foundations and may swarm indoors, causing inconvenience to occupants. It is not uncommon in more southern areas of North America.

The tick *Argas reflexus* (*F.*), commonly known as the pigeon tick, was found among other ticks taken from a bird's nest at Summerland, B.C., by J. D. Gregson of the Kamloops laboratory. Specimens believed to be of this species have been recorded from California and Montana in the United States. It has been recorded also from several European countries, Algeria, and Columbia.

The tomato russet mite, *Vasates destructor* (Keif.), was reported by J. C. Fisher of the Harrow, Ont., laboratory to have appeared on tomatoes in a greenhouse near Harrow. It was discovered in California, U.S.A., in 1940, and has since spread throughout much of that country, including several states bordering Eastern Canada. Damaging infestations have occurred in the field as well as the greenhouse. The native habitat and preferred host plants of the mite are unknown.

The furniture carpet beetle, *Anthrenus flavipes* Lec. [=*A. vorax* Waterh.], was found by E. H. Strickland of the University of Alberta severely infesting a house in Edmonton, Alta. The infestation was believed to have originated in furniture transported from Missouri, U.S.A., two years before. The species is a common pest in Egypt, India, China, Japan, Algeria, Spain, Greece, southern Russia, Mesopotamia, and the East Indies. First recorded in the United States in 1911 at Augusta, Ga., and apparently introduced from Russia, it is now present in many cities along the eastern seaboard, and is considered the most destructive household pest in Washington. It is likely to become an important pest in southern areas of North America, and in heated buildings throughout the continent. The species is extremely destructive to animal products of all kinds, particularly upholstered furniture, carpets, and brushes, and will gnaw through many other materials to reach such products.

The fungus-feeding beetle *Thes bergrothi* (Reitt.) was recorded by W. J. Brown of the Systematic Entomology Unit, Ottawa, from specimens collected

in 1926 and in 1938 at Saskatoon, Sask. The specimens taken in 1938 were from hay packing in boxes of china imported from England some months earlier. The history of the specimens taken in 1926 is not known. The species is found occasionally in the United States on imported materials, but is not known to breed in that country.

The plant bug *Irbesia arcuata* Van D. was recorded from Lethbridge, Alta., by G. A. Hobbs and C. E. Lilly of the Lethbridge laboratory. Along with *Capsus simulans* (Stål), it caused considerable damage to *Agropyron intermedium* (Host) Beauv. growing on the Lethbridge Experimental Station. The only records in the United States are from Colorado, where it was collected in small numbers at altitudes of 8,000 ft. and higher.

Two species of aphids, *Cinara murrayanae* (G. & P.) and *C. juniperi* Deg., were identified at the Forest Biology Laboratory, Indian Head, Sask. *C. murrayanae* was collected from the bark and smaller branches of lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm., at Hardisty, Alta., and Indian Head, Sask. *C. juniperi* was collected from *Juniperus communis* L. at Sault Ste. Marie, Ont. It had been recorded in 1929 on juniper imported into British Columbia from Holland (Glendenning, 1929).

The pyralid *Aphomia gularis* Zell. was found by P. Zuk of the Vancouver laboratory infesting a warehouse in Vancouver, B.C. It had been recorded on only one other occasion in Canada, namely, at Montreal, Que., in 1934. The insect, a pest of stored rice, nuts, and dried fruit, occurs commonly in eastern Asia.

A tenebrionid, *Cynaeus angustus* (Lec.), previously recorded in Canada in a local infestation of grain at Diana, Sask., in 1944, was found by H. E. Gray of the Stored Product Insect Unit, Ottawa, in abundance on cereal products in a mill at Medicine Hat, Alta., in 1952. The insect is not uncommon in the United States, where it is a comparatively minor pest of stored grain and cereal products.

Large numbers of the black larder beetle, *Dermestes ater* Deg. [=*D. cadaverinus* F.], were reported by W. J. Brown of the Systematic Entomology Unit, Ottawa, from several dwellings at Brockville, Ont., suggesting establishment in the Province. Previous records of occurrence, in 1947, involved a dwelling in Windsor, Ont., and one in Toronto, Ont. In recent years the species has been intercepted frequently in goods imported into the United States, but infestations in that country are apparently rare. It feeds on hides, leather goods, and other materials of animal origin.

The tobacco hornworm, *Phlegethontius sextus* (Johan.), was reported in destructive numbers for the first time in Canada by G. T. Manson and W. E. Butler of the Chatham laboratory; late-season damage to tobacco plants in the Leamington, Ont., area was extensive. Previous records of this insect in the Province, during 20 years or more, involved only scattered specimens of larvae and adults.

Insects New to Certain Provinces

This section includes records of insect species or genera new to certain provinces or to a geographical area within a province.

The wireworm *Agriotes obscurus* (L.), previously not known to occur in western North America except at Cobble Hill, Vancouver Island, was reported by K. M. King, of the Victoria laboratory, and R. Glendenning, of the Agassiz laboratory, from Agassiz, B.C., where it caused damage mainly to corn and rye on a single farm. It is known to be established in restricted areas of Newfoundland and Nova Scotia, at least since 1936 and probably much longer, but has not been recorded in the United States. The species is very injurious in Europe,

and it is believed that it was brought to Agassiz between 1895 and 1900 in the soil about hop plants. Infestations in Eastern Canada are believed to have originated in ballast unloaded from sailing ships.

The occurrence of the furniture carpet beetle, *Anthrenus flavipes* Lec., in a house at Edmonton, Alta., already referred to as being the first record of this insect in Canada, is believed to be the first record of any species of the genus *Anthrenus* in Alberta. Other species of the genus have been reported from British Columbia, and from Manitoba eastward to the Atlantic.

The cabbage maggot, *Hylemya brassicae* (Bouché), was identified for the first time in Saskatchewan, from flies reared from larvae collected by W. W. A. Stewart of the Saskatoon laboratory on turnips in the Regina Beach area. The insect had previously been recorded in all of the other provinces of Canada.

Larvae of the tomato hornworm, *Phlegethontius quinquemaculatus* (Haw.), were reported in the Canadian Insect Pest Survey by A. P. Arnason of the Field Crop Insect Unit, now of Ottawa, feeding on tomato foliage at Carnduff, Sask. The insect is a common pest of tomato and tobacco in southern areas of Eastern Canada.

An infestation of the beetle *Thylodrias contractus* Mots., commonly termed the odd beetle or tissue paper bug, was recorded by A. V. Mitchener of the University of Manitoba in an insect collection at the University. Earlier Canadian records were made at Ottawa in 1930, 1947, and 1950 and Montreal in 1947. In two of the earlier cases the insects fed on insect specimens, and in one case on paintings in the National Gallery; in the latter they were apparently feeding on colour pigments. The insect has also been known to injure silk hose, and to make small holes in garments.

A moderate infestation of *Psylla tuthilli* (Cald.) was observed on buffaloberry, *Shepherdia argentea* Nutt., at Morden, Man., by H. P. Richardson of the Brandon laboratory. The fruit of this native plant is used for human consumption to a limited extent, chiefly in the preparation of jellies. The insect is considered of minor economic importance.

A leaf-eating weevil, *Phyllobius oblongus* (L.), which attacks fruit trees and shade trees, was collected by officers of the Forest Biology Division on white elm at Aikenville in Wellington County, Ont., in 1950, and on walnut at Galt, Ont., in 1952. The larvae attack the roots of strawberry and other plants. Records have been received from New Brunswick in recent years, and the insect was reported from New York State, U.S.A., during the same period.

The grasshopper *Spharagemon collare wyomingianum* (Thos.) was reported in the Province of Quebec from specimens taken at Montreal, St. Thomas de Joliette, Berthier, Bois-Filion, La Trappe, and Lachute (Beaudry, 1952). It is believed to have been present for some time, but may have been introduced comparatively recently. The species frequents semi-arid areas, and has been recorded from Ontario westward to British Columbia.

The cottony maple scale, *Pulvinaria vitis* (L.), was recorded in Newfoundland by H. A. Butler of the St. John's laboratory from grape at St. John's. It occurs commonly on a wide variety of plant hosts in many other areas of Canada, notably in British Columbia and Ontario, but is of comparatively minor economic importance.

The European pine shoot moth, *Rhyacionia buoliana* (Schiff.), was found in Prince Edward Island and Newfoundland by officers of the Forest Biology Laboratory, Fredericton, N.B. Infestations were confined to provincial nurseries at Charlottetown, P.E.I., and St. John's, Nfld., and probably originated from nursery stock introduced from Ontario or elsewhere, where the insect had been

established. Pine seedlings were attacked in both nurseries, Austrian and Scots pine being infested to a greater extent than red pine. In general, however, the infestations were light and easily controlled because of the small size of the trees.

The lesser clover leaf weevil, *Hypera nigrirostris* (F.), was recorded from Newfoundland by H. A. Butler of the St. John's laboratory. It occurred on red clover and a significant reduction in yield was associated with its presence. This weevil is present and of significant economic importance in clover crops elsewhere throughout the agricultural areas of Eastern Canada.

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(Received December 4, 1953)

Colobaea and *Hedria*, Two Genera of *Sciomyzidae* New to America (Diptera: Acalyptratae)

By George C. Steyskal
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Two genera, both represented by new species, are here reported for the first time from the New World. One of them *Colobaea* (incl. *Ctenulus*), is well known in the palaearctic region; the other, *Hedria*, is new, although its type has been mistaken for the palaearctic species *Elgiva lineata* Fallén.

Genus *Colobaea* Zetterstedt

Colobaea Zetterstedt, 1838, Insecta Lapponica: 762, one species, *Opomyza bifasciella* Fallén; 1847, Dipt. Scand. 6: 2428; Hendel, 1923, Konowia 2: 207; Séguy, 1934, Faune de France 28: 266.

Calobaea (Zett.) Hendel, 1902, Abhandl. zool.-bot. Ges. Wien 2: 49; Kertész, 1915, Allattani Közl. 14: 106; Lundbeck, 1923, Vidensk. Medd. Dansk. nat. Foren. 76: 101; Sack, 1939, in Lindner, Die Fliegen d. pal. Region, Fasc. 37: 25; Enderlein, 1939, Veröff. Deut. Kolon. Mus. Bremen 2: 202; Verbeke, 1948. Bull. Mus. roy. Hist. nat. Belgique 24: 13.

Ctenulus Rondani, 1856, Dipt. Ital. Prodr. 1: 107, "Spec. Typ.: *Opomyza pectoralis* Staeger (In litteris)"; Hendel, 1901, Wien. entom. Ztg. 1901: 89; 1902, Abhandl. zool.-bot. Ges. Wien 2: 83; 1923, Konowia 2: 210; Lundbeck, 1923, Vidensk. Medd. Dansk. nat. Foren. 76: 101; Séguy, 1934, Faune de France 28: 283; Sack, 1939, in Lindner, Die Fliegen d. pal. Region, Fasc. 37: 32; Verbeke, 1948, Bull. Mus. roy. Hist. nat. Belgique 24: 15. *New Synonym.*

The genus *Ctenulus* was considered by Hendel (1901, 1902, 1923), Kertész, and Séguy to be Tetanocerine, but Sack showed that it belongs with the Scio-

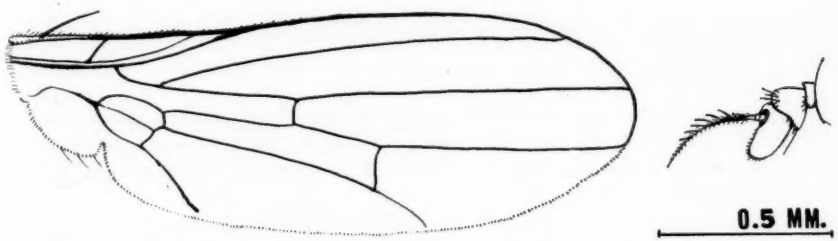


Fig. 1. *Colobaea americana* n. sp. Wing and antenna.

myzinae and Verbeke followed him in this reference. Both Sack and Verbeke separated *Colobaea* and *Ctenulus* on the character of the anal vein of the wing, which in the former does not attain the margin of the wing, while in the latter it supposedly does. However, Hendel (1902) stated "Die Analader erreicht bei keiner Art den Flügelrand . . ." and Séguy republished Hendel's figure of the wing of *Ctenulus distinctus*, showing the anal vein falling short of the margin.

Supposing that Hendel was correct in his statement regarding the anal vein, and in view of the fact that both genera share the following characters, there no longer seems to be any basis for maintaining the distinctness of the genera.

Anal vein evanescent before attaining margin of wing.

Basal cell of wing small.

Vein R_1 ending basad of anterior crossvein; pterostigma very small, vein Sc ending close to R_1.

Fore coxae lengthened, with several bristles, as many as five.

Dorsocentral bristles consisting of two strong pairs, preceded by a series of outstanding hairs.

Hind femora with a double ventral row of distinct but not very long bristles.

Two fronto-orbital bristles.

Ocellar triangle not prolonged, mid-frontal stripe not developed.

Front matt, not shining.

In *Colobaea bifasciella* there are a pair of transverse brown bands on the wing, one preapical and one in the level of the posterior crossvein; in *Ctenulus* these bands are absent, but the cross-veins are sometimes darkened. The arista of *Colobaea* has long hairs basidorsally and some ventrally; in *Ctenulus* there appear to be no ventral hairs. These characters hardly seem to be of generic value.

***Colobaea americana*, species nova**

Male and female. Length of body, 1.7 to 2.1 mm.

Head yellow; black behind above lowest third of eye and on front except narrow anterior margin (especially in corners and between antennae). Front matt except shining parafrontal stripes and ocellar triangle. Parafrontal stripes extending nearly 0.2 distance from eye to meson and somewhat more than halfway from anterior ocellus to anterior margin of front. Shining ocellar triangle not extending laterad or anterad of ocelli. Face and clypeus shining. Orbits with complete narrow white-pruinose band. Parafrontal stripes and ocellar triangle with slight whitish pruinosity. Cheeks one-sixth of eye-height, with two irregular rows of longish setae along ventral edge.

Eyes of both sexes, but especially the male, with larger ommatidia anteriorly. The color of the eyes of one of the 1946 specimens, upon being held in a moist jar for several hours, was revealed as dark green below, grading without sharp

demarcation to deep purplish above, with a small coppery spot at posterior margin just below middle.

Palpi and proboscis yellow.

Antennae as in fig. 1; first two segments yellow; third segment black. Arista brownish, with short whitish hairs and a few longer setulose hairs dorsally.

Chaetotaxy of head: 2 long fronto-orbitals, 1 ocellar, 1 inner vertical, 1 outer vertical, 1 postvertical, 1 genal.

Thorax black, with yellowish lateral stripe from anterior margin to base of wing. Propleura and more or less of lower part of mesopleura yellow. Very narrow dorsal margin of mesopleura also yellow. Prosternum and ventral aspect of remainder of thorax yellow. Thorax with very thin whitish pruinosity on most of surface, the pale humeral stripes more distinctly silvery.

Chaetotaxy of thorax: 2 strong dorsocentrals preceded by a few distinct hairs; 1 humeral, 2 notopleural, 1 presutural, 1 supraalar, 1 postalar, 0 prescutellar, intradorsocentral hairs sparsely disposed in approximately 4 rows, 2 scutellar, 1 well developed but small propleural, 0 mesopleural bristles or hairs, 1 or 2 small pteropleurals, sternopleura with scattered hairs, of which 1 or 2 dorsal ones are bristly.

Legs yellow, including all coxae and entire middle and hind legs. Fore femora with apical third (male) or half (female) black, the color extending a little farther basad dorsally; fore tibiae wholly black; fore tarsi with basal three segments black, apical two yellowish.

Chaetotaxy of legs: fore coxae with lateral row of 3 to 5 small bristles and a few hairs; fore femora with moderate hairs beneath and several long bristles above; fore tibiae with a single preapical; middle femora with median anterior bristle; hind femora of male with double ventral row of bristly hairs which are approximately one-third as long as greatest diameter of femur and in both sexes with 1 or 2 long subapical dorsal bristles; hind tibiae with 1 preapical; hind coxae without hairs above.

Wings as in fig. 1, pale yellowish, with yellowish veins. Halteres, squamae and squamal ciliae yellowish.

Abdomen shining; in male black, more or less yellowish basilaterally, posterior segmental margins yellow, penultimate tergite yellow, hypopygium shining black; in female brown, venter and penultimate tergite yellow, ultimate segment black, the terminal segments retracted.

Holotype male, allotype female, and paratype male, Aylmer, Quebec, 31 July 1946 (G. E. Shewell); paratype female, Aweme, Manitoba, 11 August 1917 (N. Criddle); all in Canadian National Collection, Ottawa.

Our species is close to *Ctenulus distinctus* Meigen (sec. Hendel, 1902, and Sack), but differs in having a shorter and wholly black third antennal segment, well developed sternopleural bristle, and fore femora more extensively black apically.

Genus *Hedria* Steyskal, novum
(Generitype, *H. mixta* Steyskal, species nova)

The lack of a propleural bristle and the presence of a well developed mid-frontal stripe and one pair of appendages on the hypopygium (male) show this genus to be a member of the subfamily Tetanocerinae. It may be separated from other genera by the following characters: second antennal segment equal in length to third segment; arista thickly white-pubescent; ocellar bristles lacking; 2 fronto-orbital bristles; 1 or 2 pairs of scutellars; 1 dorsocentral; 0 prescutellar; 1 humeral; 2 notopleural; 0 or 1 presutural; 1 supraalar; 2 postalar; 0 pleural or vallar bristles;

a few hairs on propleura, mesopleura, and sternopleura; no hairs on metapleural callus; lunule well exposed; hind coxae without dorsal hairs; wings without well developed pattern, with only a few clouds in apical cells; posterior crossvein S-curved; face without median spot.

The genus is apparently related to *Elgiva*, with which it has been confused (v.i.), in spite of the fact that that genus has vallar and ocellar bristles and differs in other respects.

***Hedria mixta*, species nova**

Elgiva lineata Johnson (non Fallén), Melander, 1920, Ann. Entom. Soc. Amer. 13: 322 (record of occurrence in Maine); Johnson, 1925, Occas. Pap. Boston Soc. Nat. Hist. 7: 252 (Maine; Mass.); Johnson, 1927, Biol. Survey Mt. Desert Region, pt. 1: 215.

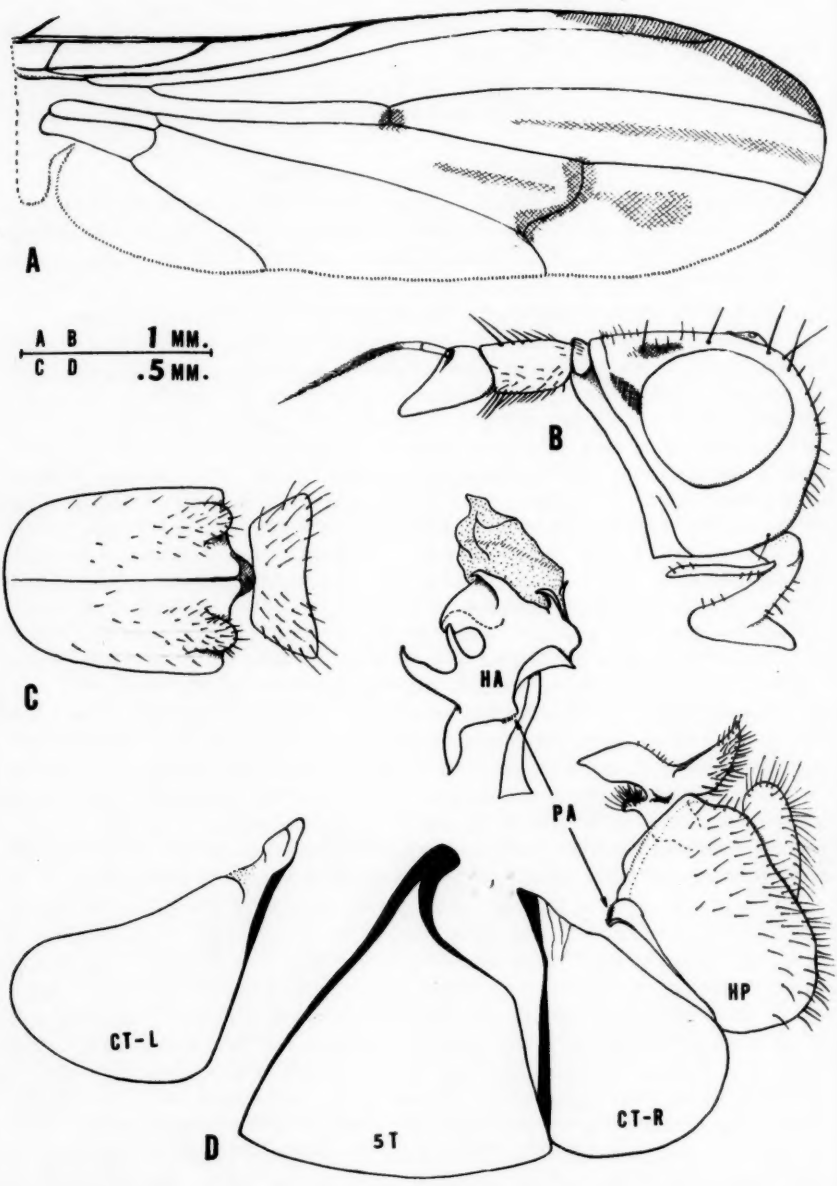
Male and female. Length of body: male, 6-6.5 mm; female, 7-8 mm.

Color of entire insect tawny, only apical two or three tarsal segments dark brown. Head with dull black orbito-antennal spot and smaller, elongated spot at anterior fronto-orbital bristle (cf. fig. 2B). Eyes of Hamburg, Michigan, specimen dark olive-green with two complete indigo longitudinal bands in middle upon being held in moist chamber. Dorsum of thorax with complete, parallel-sided, yellow, brown-margined, pruinose median stripe and similar broad lateral margins. Broad upper edge of pleura in entire length, including metapleural callus, somewhat brownish. Remainder of thorax and coxae pale grayish pruinose. Legs, except coxae, shining. Abdomen lightly pruinose dorsally, shining laterally. Face and cheeks whitish pruinose; a pair of broad shining stripes extend from base of antennae to oral margin. Lunule, mid-frontal stripe, ocellar triangle, and back of head (except cerebral pruinose spots) shining. Frontal orbits shining only from vertex to short distance before anterior fronto-orbital bristle. First and second antennal segments shining, the third dull.

Head as in fig. 2B; front flattish; mid-frontal stripe parallel-sided, a little wider than ocellar triangle, rounded at anterior margin of front, concave. Face elevated in middle, with carina in upper half extending between antennae. Antennae compressed, second segment carinate dorsally. Arista yellowish, with thick whitish pubescence. Bristles as figured: 2 fronto-orbitals, 2 verticals, 1 post-vertical, 0 ocellar (ocellar triangle with a few short hairs only), 1 small genal. Palpi in male with a few short hairs, in female with numerous longer hairs.

Thorax 1.5 times as long as wide, slightly narrower anteriorly; scutellum half as long as wide. Chaetotaxy of thorax: 1 dorsocentral, 0 prescutellar, 1 humeral, 2 notopleural, 1 supra-alar, 2 postalar, 0 or 1 presutural (one female from Mt. Desert shows a well developed pair of presuturals); scutellum with 1 pair of erect convergent apicals (2 males have a single subdorsal lateral and one female has a pair of such); pleural bristles lacking; a very few fine hairs on lower propleura, posterior mesopleura, middle pteropleura, and upper sternopleura; vallar bristles lacking, but several specimens show one or two small hairs on the vallum; prosternum bare; mesosternum with 1 pair of bristles behind middle coxae.

Legs of moderate length and thickness, hind femora in female attaining, in male slightly surpassing tip of abdomen. Fore covae with 1 lateral bristle in apical fourth and very few hairs; hind coxae without dorsal hairs. Fore femora with several short, stout bristles dorsally; middle femora with median anterior bristle; hind femora with posterior and anterior rows of 5-7 short, stout, unequally spaced ventral bristles in apical half and 1 or 2 poorly distinguished subapical dorsal bristles. Fore and hind tibiae each with one preapical.



Figs. 2A-2D *Hedria mixta* n. sp. 2A, wing; 2B, head; 2C, fourth and fifth abdominal sternites; 2D, male postabdomen. CT-L, compound tergite, left view; CT-R, same, right view; HA, hypandrium; HP, hypopygium (ninth tergite); PA, point of attachment of hypandrium to hypopygium; 5T, fifth tergite.

Wings as in fig. 2A; yellowish, with brown clouds as indicated; veins yellowish; halteres and squamae yellowish.

Abdomen without bristles, evenly covered with fine hairs, erect in male, reclinate in female. Female apical somites a little protruding. Male terminalia as in fig. 2C and D; 4th sternite with a pair of mammiform processes and a median lobe; 5th sternite pale and soft; hypopygium (HP) broadly open ventrad of paraanal lobes, surstyli posterior in position, tripartite; hypandrium (HA) attached to anteroventral corner of hypopygium (point labeled PA), anterior strip sinuous and asymmetrical, lateral parts also slightly asymmetrical (dextral half figured), with five processes, of which the middle one is broad and inflexed; aedeagus strongly asymmetrical.

Holotype: male, Hay River, Northwest Territories, 10 Sept. 1932 (Owen Bryant, No. 352), in USNM,* no. 61843; allotype; female, Mount Desert, Maine, 7 August 1926, Salisbury Cove (C. W. Johnson), USNM; paratypes: female, same data as allotype, USNM; male and female, same, CNC**; male and female, same, 11 August 1926, Academy of Natural Sciences of Philadelphia; 3 males and 2 females, same, Museum of Comparative Zoology at Harvard College; male, same, in author's collection; male and female, Wabamun, Alberta, 6 August 1936 (E. H. Strickland), University of Alberta; male, Nordegg, Alberta, 3 August 1921 (J. McDunnough), CNC; 4 males and 2 females, Waskesiu Lake, Saskatchewan, 26 July 1939 (A. R. Brooks), CNC; female, Hamburg, Livingston County, Michigan, 13 August 1933 (Geo. Steyskal), in author's collection; male, Door County, Wisconsin, 8 August 1929 (Chas. L. Fluke), University of Wisconsin.

The name is one selected many years ago by John R. Malloch, who recognized the species as distinct from *Elgiva lineata*, but never published on it.

*USNM=United States National Museum.
**CNC=Canadian National Collection.

(Received April 28, 1953)

Avian Mallophaga from Quebec[1]

By W. E. WHITEHEAD
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Following the lead set by Dr. George M. Stirrett, (Canadian Entomologist, July, 1952), the following records of Mallophaga from avian hosts taken in the province of Quebec have been assembled. It is hoped that others will record collections made in their respective provinces, so that eventually records and the distribution of species may be available for the Dominion.

The following species were largely collected by the author, with some assistance from the late Dr. W. E. Swales. The specimens form part of the Macdonald College Collection.

Identifications have been made, at various times, by Dr. H. S. Peters, Fish and Wildlife Service, U.S. Department of the Interior, Dr. G. B. Thompson, formerly of the British Museum, Dr. F. H. Wilson, Champlain College and Dr. E. W. Stafford, Mississippi State College.

Family *Menoponidae*

Menopon kuwanii Kell. & Clay

Double-crested cormorant, *Phalacrocorax auritus*, Quebec, 1938.

Menopon gallinae Linn.

Guinea fowl, *Numida meleagris*, Ste. Anne de Bellevue, 1933; robin, *Turdus migratorius*, Ste. Anne de Bellevue, 1932. (Straggler from domestic fowl).

1Contribution from the Faculty of Agriculture, McGill University, Macdonald College, Que., Canada. Journal Series No. 326.

Menopon colaptis Durrant
Flicker, *Colaptes auratus*, Ste. Anne de Bellevue, 1931.
Menopon productum Piaget
Golden pheasant, *Chrysolophus pictus*, Foster, 1950.
Menopon sp. near *albofasciatum* Piaget
Gtr. scaup duck, *Nyroca marila*, Quebec, 1933.
Holomenopon loomisii (Kell.)
Black duck, *Anas rubripes*, Quebec, 1932.
Eomenacanthus stramineus Nitz.
Domestic fowl. Widespread.
Colpocephalum laticeps Kell.
Gt. blue heron, *Ardea herodias*, Ste. Anne de Bellevue, 1936.
Colpocephalum sp.
Killdeer, *Oxyechus vociferus vociferus*, Ste. Anne de Bellevue, 1936.
Colpocephalum sp.
Kingbird, *Tyrannus tyrannus*, Pte. Claire, 1937.
Actornithophilus funebre (Kell.)
Herring gull, *Larus argentatus*, Ile Perrot, 1935.
Actornithophilus sp.
Belted Kingfisher, *Megaceryle alcyon*, Ile Perrot, 1935.
Myrsidea americana Kell.
Crow, *Corvus brachyrhynchos*, Ste. Anne de Bellevue, 1935.
Myrsidea dissimilis Kell.
Purple martin, *Progne subis*, Ste. Anne de Bellevue, 1931, 1932, 1933, 1939, 1944.
Myrsidea quadrimaculatus Piaget
Red-wing, *Agelaius phoeniceus*, Quebec, 1938.
Machaerilaemus latifrons Carr.
Rusty blackbird, *Euphagus carolinus*, Ste. Anne de Bellevue, 1933.
Menacanthus chrysophaeum (Kell.)
Meadowlark, *Sturnella magna*, Ste. Anne de Bellevue, 1933.
Menacanthus praecursor (Kell.)
Flicker, *Colaptes auratus*, Ile Perrot, 1935.
Menacanthus spiniferus Piaget
Starling, *Sturnus vulgaris*, Ste. Anne de Bellevue, 1933.
Dennyus dubius Kell.
Chimney swift, *Chaetura pelagica*, Ste. Anne de Bellevue, 1933.
Trinotum querquedulae Linn.
Baldpate, *Mareca americana*, hooded merganser, *Lophodytes cucullatus*, American merganser, *Mergus merganser americanus*, Lake of Two Mountains, 1934, black duck, *Anas rubripes*, Quebec, 1934; baldpate, *Mareca americana*, Lake St. Francis, 1935.
Eidmanniella pustulosa (Nitz.)
Gannet, *Moris bassanae*, Quebec, 1945.

Family *Laemobothridae*

Laemobothrium tinnunculi (Linn.)
Golden eagle, *Aquila chrysaetos canadensis*, Zoological Garden, Quebec, 1937.

Family *Ricinidae*

Ricinus sp. *leptosomus* Carr.?
Kingbird, *Tyrannus tyrannus*, Pte. Claire, 1937.
Ricinus sp. *angulatus* (Kell.)?
Kingbird, *Tyrannus tyrannus*, Pte. Claire, 1937.

Family *Philopteridae*

Goniodes dispar Nitz.
Hungarian partridge, *Perdix perdix perdix*, Quebec, 1933.

Goniodes tetraonis Linn.
Willow ptarmigan, *Lagopus lagopus*, Wolstenholme, 1933.

Goniodes colchicus Denny
Golden pheasant, *Chrysolophus pictus*, Foster, 1950.

Goniocotes bidentatus Scop.
Domestic pigeon, *Columba* sp., Ste. Anne de Bellevue, 1934.

Oxylipeurus mesopelios mesopelios Giebel
Golden pheasant, *Chrysolophus pictus*, Foster, 1950.

Anatoecus dentatus Scop.
Gtr. scaup duck, *Nyroca marila*, Quebec, 1933; black duck, *Anas rubripes*, Quebec, Ste. Anne de Bellevue, 1934; old squaw, *Clangula hyemalis*, Lake of Two Mountains, 1934; blue goose, *Chen caerulescens*, Sugluk Inlet, 1935; domestic duck, Ste. Anne de Bellevue; wood duck, *Aix sponsa*, Lake of Two Mountains, 1952.

Eustrigiphilus ceblebrachys (Nitz.)
Snowy owl, *Nyctea nyctea*, Ft. Chimo, 1933; hawk owl, *Surnia ulula caparoch*, Ste. Anne de Bellevue, 1934.

Philopterus duplicatus (Piaget)
Belted Kingfisher, *Megaceryle alcyon*, Ile Perrot, 1935.

Philopterus graviceps (Kell.)
Loon, *Gavia immer*, Ste. Genevieve, 1935; Ste. Anne de Bellevue, 1947.

Philopterus major Waterston
Wilson's snipe, *Capella delicata*, Ile Perrot, 1935.

Philopterus cursor Nitz.
Short-eared owl, *Asio flammeus*, Quebec, 1938.

Philopterus pertusus (Nitz.)
Coot, *Fulica americana*, St. Anicet, 1936.

Philopterus subflavescens Geoff.
Snow bunting, *Plectophenax nivalis*, Rigaud, 1936; northern shrike, *Lanius borealis*, Quebec, 1938.

Philopterus cordiceps Giebel
Red-wing, *Agelaius phoeniceus*, Ste. Anne de Bellevue, 1933.

Philopterus domesticus Kell.
Purple martin, *Progne subis*, Ste. Anne de Bellevue, 1932, 1939.

Philopterus quisculi (Osb.)
Bronzed grackle, *Quisculus quiscula*, Ste. Anne de Bellevue, 1934.

Penenirmus californiensis (Kell.)
Yellow-bellied sapsucker, *Sphyrapicus varius*, Ste. Anne de Bellevue, 1933, 1937.

Penenirmus jungens (Kell.)
Flicker, *Colaptes auratus*, Ste. Anne de Bellevue, 1948.

Philopterus gonothorax Giebel
Iceland gull, *Larus leucopterus*, Quebec, 1939.

Philopterus corvi Linn.
Crow, *Corvus brachyrhynchos*, Ste. Anne de Bellevue, 1932.

Philopterus sp.
Killdeer, *Oxyechus vociferus vociferus*, Ste. Anne de Bellevue, 1936.

Degeeriella fusca Nitz.
Marsh hawk, *Circus hudsonius*, Baie d'Urfe, 1933; pigeon hawk, *Falco columbarius*, Gaspe, 1935; red-tailed hawk, *Buteo borealis*, Quebec, 1946; sparrow hawk, *Falco sparverius*, Ste. Anne de Bellevue, 1949.

Degeeriella marginatula Harr.
Flicker, *Colaptes auratus*, Ste. Anne de Bellevue, 1931.

Degeeriella illustris (Kell.)
Red-wing, *Agelaius phoeniceus*, Ste. Anne de Bellevue, 1933; rusty blackbird, *Euphagus carolinus*, Ste. Anne de Bellevue, 1933.

Degeeriella gracilis Nitz.
Purple martin, *Progne subis*, Ste. Anne de Bellevue, 1933.

Degeeriella picturata Osb.
Meadowlark, *Sturnella magna*, Ste. Anne de Bellevue, 1933.

Degeeriella vulgata Kell.
Kingbird, *Tyrannus tyrannus*, Pte. Claire, 1930; robin, *Turdus migratorius*, Ste. Anne de Bellevue, 1932.

Degeeriella sp.
Kingbird, *Tyrannus tyrannus*, Pte. Claire, 1937.

Brüelia nebulosa (Burm.)
Starling, *Sturnus vulgaris*, Ste. Anne de Bellevue, 1931, 1932, 1933.

Brüelia rotundata Osb.
Crow, *Corvus brachyrhynchos*, Ste. Anne de Bellevue, 1932, 1934.

Brüelia longa (Kell.)
Purple martin, *Progne subis*, Ste. Anne de Bellevue, 1939.

Pectinopygus bassanae (Fab.)
Gannet, *Moris bassana*, Quebec, 1945.

Rallicola advena (Kell.)
Coot, *Fulica americana*, St. Anicet, 1936, Lake St. Peter, 1952.

Columbicola columbae (Linn.)
Domestic pigeon, *Columba* sp., Ste. Anne de Bellevue, 1935.

Esthiopterum botauri Osb.
Bittern, *Botaurus lentiginosum*, Ile Perrot, 1935.

Anaticola crassicorne (Scop.)
American merganser, *Mergus merganser americanus*, Ste. Genevieve, 1934.

Esthiopterum anseris Linn.
American merganser, *Mergus merganser americanus*, Ste. Anne de Bellevue, 1934; black duck, *Anas rubripes*, Quebec, 1934; baldpate, *Mareca americana*, Lake St. Francis, 1934; snow goose, *Chen hyperboreus*, Cap Tourmente, 1934.

Esthiopterum luridum (Nitz.)
Coot, *Fulica americana*, St. Anicet, 1936.

Esthiopterum toxocerum (Nitz.)
Double-crested cormorant, *Phalacrocorax auritus* Bic, 1935.

Quadraceps similis (Giebel)
Spotted sandpiper, *Actitis macularia*, Ste. Anne de Bellevue, 1938.

(Received April 28, 1953)

An Application of the Linear Discriminant Function to Insect Taxonomy[1]

By R. S. Bigelow[2] and C. Reimer[3]

This paper is a report on the applicability of the linear discriminant function to insect taxonomy. Mather and Dobzhansky (1939) and Cox (1953) applied this technique to problems in insect taxonomy, but the former study was concerned with detecting a difference between samples, and the latter used the function only secondarily. In this paper, discriminant functions were calculated from several combinations of linear characters in males of two closely related species of grasshopper, *Arphia pseudonietana* (Thomas) and *A. conspersa* Scudder, to determine: (a) whether a reliable criterion could be found for relatively inexperienced workers to determine individual specimens with a predictable degree of precision; and (b) which characters, or combination of characters, would provide the most reliable criteria.

Individuals of these two species can be distinguished by an experienced taxonomist, but are sufficiently similar to render difficult their determination by an inexperienced worker. Both species have been known for some 80 years, and their taxonomy has received a considerable amount of study. Hebard (1936) provided a key to separate them, as follows:—

"Occiput and juncture of vertex with frontal costa less evenly convex. Appears adult in the Spring. Wing disk pink, thru orange to yellow, band narrow to medium broad. Caudal tibiae with dark section usually almost entirely supplanted by buff or light glaucous..... *Arphia conspersa* Scudder.

"Occiput and juncture of vertex with frontal costa evenly convex. Appears adult in the Summer. Wing disk rich pink (very rarely yellow), band very broad. Caudal tibiae usually blackish to proximal pale annulus..... *Arphia pseudonietana pseudonietana* (Thomas)."

Though the above characters were well chosen, and are adequate to identify the majority of specimens encountered, there is an overlapping in all of them. The wing band, the most distinctive character used, can be examined only when the wings have been spread, which entails considerable time and some possibility of damage. The use of this key by an inexperienced worker involves risk of error, and the addition of one or more criteria would therefore be useful. In any case, these two species were adequate for testing the applicability of discriminant functions to insect taxonomy generally.

The following five characters were measured: (a) length of hind femur; (b) maximum width of hind femur; (c) interocular space (minimum distance between the eyes across the vertex); (d) clypeo-ocellar distance (vertical distance from the frontoclypeal suture to the median ocellus); and (e) length of tegmen (measured from the dorsal posterior extremity of the pronotum to the distal extremity of the tegmen).

Thirty-six male specimens of each species were used in the calculations. Both samples were collected over a considerable period of years, by a number of collectors, and their distribution by provinces was as follows:—

	Manitoba	Saskatchewan	Alberta	British Columbia	Unlabelled	Total
pseudonietana	2	5	1	27	1	36
conspersa	20	10	5	1	0	36

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One of the authors made independent duplicate measurements of all five characters in each species, by means of a Zeiss Opton Stereomicroscope equipped with a squared eyepiece micrometer that had been calibrated against a stage micrometer to the nearest 0.01 mm. To increase the speed and precision of taking these measurements, a mechanical stage intended for use with a compound microscope was adapted to the Stereomicroscope. By this means the grid lines of the eyepiece micrometer could be aligned rapidly and accurately, and the specimen traversed in a horizontal plane. Before each reading the character being measured was oriented in a horizontal plane by ensuring that each of its extremities was in sharp focus.

The errors of measurement for each character were estimated from the differences between the duplicate measurements. The standard deviations corresponding to these errors were as follows: length of femur, ± 0.05 mm.; width of femur, ± 0.02 mm.; interocular space, ± 0.01 mm.; clypeo-ocellar distance, ± 0.02 mm.; and length of tegmen, ± 0.08 mm. Means of the duplicate readings were used throughout the statistical analysis described below. The standard errors of measurement of these means are $\sqrt{\frac{1}{2}}$ times the above standard deviations.

The intraspecific variances for each of the five characters were of the same order for both species. They were accordingly pooled for each character. The corresponding specific means ($\bar{X}_p$, $\bar{X}_c$), standard deviations (s), and t values appropriate for testing the differences between these means were:—

Character	$\bar{X}_p$(mm.)	$\bar{X}_c$(mm.)	s(mm.)	$t=\frac{\bar{X}_p-\bar{X}_c}{s\sqrt{\frac{2}{36}}}$
length of femur	12.59	11.15	±0.67	9.1
width of femur	3.39	3.38	±0.21	0.3
interocular space	1.37	1.21	±0.07	10.0
clypeo-ocellar distance	1.81	1.63	±0.09	8.7
length of tegmen	21.20	19.39	±1.21	6.4

These t values, referred to tables of the normal probability integral,* indicate that the average femur width was of the same order in the two samples, but that means of the other characters differed markedly between species. Each of these four differences was so great that the probability of its chance occurrence in random samples of this size was less than one in a billion. The discriminating power of each of these four characters was then determined. On the assumption that the mid-point between the specific means is the critical value for a particular character, a specimen would be misdetermined if its measurement differed from the mean of its species by at least half the difference between the specific means, provided this deviation was in the direction of the other species. The probability of misdetermination is accordingly obtained by calculating another t value for each character, viz.,

$$t = \frac{\frac{1}{2}(\bar{X}_p - \bar{X}_c)}{s},$$

where X_p, X_c, and s are defined as above, and this t value is referred to tables of

*For small samples, say of less than 16, tables of Student's t distribution should be used instead.

the normal probability integral. In this case only one tail of the curve is taken into consideration.

The probabilities of misdetermination were: length of femur, 0.14; interocular space, 0.12; clypeo-ocellar distance, 0.15; and length of tegmen, 0.23. Thus the discriminating precision of these characters separately ranged from 77 per cent for tegmen length to 88 per cent for interocular space. Although each of these four characters was adequate for discriminating between the two samples, none by itself provided a sufficiently reliable criterion for identifying individual specimens with, say, 95 per cent precision.

Greater precision can be obtained by combining two or more characters in a linear discriminant function (Fisher, 1936). The degree of precision thus obtained depends not only on the precision of the separate characters but also on the nature of their interrelations. This function is expressed in the following equation:—

$$z = a_1X_1 + a_2X_2 + a_3X_3 + \ldots$$

where X_1, X_2, X_3 . . . represent the characters measured and a_1, a_2, a_3 . . . the appropriate weighting factors. The calculation of these weighting factors is outlined by Goulden (1952).

The probabilities of misdetermination for a number of discriminant functions each employing a different combination of characters were: femur length and interocular space, 0.083; femur length, interocular space, and tegmen length, 0.082; femur length, interocular space, tegmen length, and clypeo-ocellar distance, 0.083; femur length and femur width, 0.043; femur length, femur width, and interocular space, 0.019; and femur length, femur width, interocular space, and clypeo-ocellar distance, 0.017.

Femur width, though useless by itself as a means of discrimination, is a component of the most precise of the above functions. The greatest precision obtained without it was 92 per cent, whereas the least precision obtained with it was 96 per cent. On the other hand, the addition of certain characters (e.g., tegmen length, clypeo-ocellar distance) did not appreciably increase the discriminating precision, despite the fact that the value of each of these characters differed markedly between species.

Apparent anomalies such as these can occur as the result of different interrelations of the different characters, both within and between species. These interrelations should therefore be considered in the selection of characters for use in discriminant functions. The factors involved are complex, particularly when more than two characters are employed, and their full discussion is beyond the scope of this paper. Nevertheless, in view of the remarkable discriminating power of femur width when used together with femur length, it may be useful to consider their interrelations in greater detail. When combined in a two-character discriminant function, they gave 96 per cent precision, greater than any other pair of characters measured. Moreover, interspecific differences in femur shape could be detected subjectively. It appears, therefore, that the effectiveness of combinations employing these two characters was due to the difference in femur shape between species, which was large relative to the variation in femur shape within species. The uniformity of femur shape within species was reflected in the high degree of correlation between these characters ($r = 0.80$). It should be possible to express interrelations of this nature in discriminant functions, even if shape differences were too small to be detected subjectively, or if they concerned widely separated characters, e.g., on the dorsum and sternum. On the other hand, characters having a very low correlation within species may possibly also yield precise discriminant functions, e.g., characters relatively independent of specimen size.

Ratios of two characters may also be employed in insect taxonomy, either by themselves or in discriminant functions along with other characters. However, the distribution of ratios of two linear characters may deviate appreciably from a normal distribution, in which event a transformation (change of scale) is required. For example, there was some evidence of non-normality in the distribution of the ratios of femur length to femur width. The logarithms of these ratios gave a somewhat less precise criterion than did the linear combination of the characters, the probability of misdetermination with the ratios being 0.063 as compared to 0.043 with the discriminant function. However, where large numbers of characters (say, five or more) are to be used in a discriminant function, the use of ratios might be advisable since they combine two characters and thus reduce the total number of *a* values that must be calculated.

Of the above functions, that for femur length, femur width, and interocular space would be the most suitable for practical application. With the *a* values substituted, this function becomes:—

$$z = X_1 - 3.08\ X_2 + 4.74\ X_3,$$

where X_1 = femur length, X_2 = femur width, and X_3 = interocular space, and all characters are measured in a common unit. If, for example, a specimen had: femur length = 11.47 mm., femur width = 2.99 mm., and interocular space = 1.38 mm., its z value would be obtained as follows:—

$$z = (11.47) - 3.08\ (2.99) + 4.74\ (1.38)\ \text{mm.}$$
$$= 8.8\ \text{mm.}$$

The z values obtained in this way had an intraspecific standard deviation of $\pm$ 0.51 mm. The mean z values were 8.59 $\pm$ .09 mm. and 6.47 $\pm$ .09 mm. for *pseudonietana* and *conspersa* respectively. The critical z value is the mid-point between the means, i.e., 7.53 mm. Specimens giving a value lower than this would be assigned to *conspersa*, those giving a higher value to *pseudonietana*.

Provided the samples used are representative, individual males of either species could be thus determined with a precision of 98 per cent by anyone capable of taking the measurements accurately and familiar with the necessary arithmetic. As a test, the function was applied to a total of 174 specimens, none of which had been used in its calculation. The regional distribution of these specimens was as follows:—

	U.S.A.	Manitoba	Saskatchewan	Alberta	British Columbia	Northwest Territories	Total
pseudonietana	6	0	15	3	5	0	29
conspersa	0	31	72	11	4	27	145
							174

Three (1.7 per cent) of these 174 specimens were misdetermined with the function, which compares favourably with the expected value of 1.9 per cent.

When used along with Hebard's key, this method should give even greater precision, since qualitative characters such as those used in the key should not be appreciably associated with the type of quantitative character used in discriminant functions.

It seems reasonable to conclude that discriminant functions may serve a useful purpose in insect taxonomy by increasing the speed and accuracy of determinations by inexperienced workers and, in some instances, by making determinations by such workers possible. In addition, discriminant functions may be useful for detecting small morphological differences that are beyond the scope of the classical descriptive methods, as shown by Mather and Dobzhansky (1939) in their work on races of *Drosophila pseudoobscura*. In short, such

statistical techniques may possibly provide a tool enabling any entomologist to make accurate determinations, and taxonomists in particular to carry out objective analyses of both inter- and intra-specific variation.

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(Received August 26, 1953)

A Strain of *Bacillus cereus* Fr. and Fr. Pathogenic for the Larch Sawfly, *Pristiphora erichsonii* (Htg.)[1]

By A. M. HEIMPEL[2]

Introduction

During the summer of 1950, several strains of *Bacillus cereus* Fr. and Fr. were isolated from dead and dying larvae of the larch sawfly, *Pristiphora erichsonii* (Htg.). These strains were found to be identical and were held under the culture number Pr-1017. Preliminary feeding tests indicated that the bacterium was a pathogen of the sawfly and further feeding tests, conducted in 1951, corroborated this fact. The results of the 1951 feeding tests are reported in this paper.

To the knowledge of the writer, this is the first published report of a strain of *B. cereus* that is a pathogen of a hymenopteron. Previously the concensus was that *B. cereus* was specifically a pathogen of *Lepidoptera* (6, 7, 11). Since 1950, strains of *B. cereus* have been reported as pathogens of three species of *Lepidoptera*: *Ephestia kuehniella* Z. (3), *Colias philodice eurytheme* Boisduval (12), and *Carpocapsa pomonella* (Linn.) (13, 8). Reports prior to 1950, of the pathogenicity of *B. cereus*, are summarized by Steinhaus (11).

Materials

The identification of Pr-1017 as a stain of *B. cereus* was accomplished by applying the biochemical tests outlined in Bergey's Manual of Determinative Bacteriology (1). Besides these tests, the fact that the strain produces lecithinase categorizes it as *B. cereus* (2, 4).

The spore material was prepared by growth on cellophane laid over a semi-solid medium according to the method of Reed and McKercher (9). Dry spore material was retained in sterile vials until spore-suspensions were required.

Spore-suspensions were made by mixing spore material in sterile, distilled water. Plate counts of the suspensions, made immediately before use, varied between 10 and 11 million spores per cubic centimetre.

Spore material prepared in the spring of 1951 was still viable in 1952. During this period, the virulence of the bacteria for the larch sawfly had not decreased to any noticeable degree.

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Method

Laboratory feeding tests

The rearing chamber used for these tests consisted of a lantern globe set on a water can with a small hole in the top. The larch foliage was first dipped in bacterial spore suspensions, and was firmly fixed in the hole so that the cut end of the twig was immersed in water. The lantern globe, with the smaller end covered with tissue paper, enclosed the foliage. In each rearing unit, approximately 10 to 15 larvae were placed on the foliage to feed. Control units were set up in a similar fashion except that the foliage was dipped in sterile, distilled water. The rearing chambers were examined daily and dead larvae were removed.

Field tests

Two larch stands (each approximately five acres in area) designated as plots A and E, were selected for field tests. Branches were selected in each plot and trays, built of 1 by 3 inch lumber covered with factory cotton, were set up under each branch. The trays served to catch dead larvae that dropped off the branches. Approximately 200 to 300 young larvae were placed on each of the test branches to feed.

Six branches in each plot were sprayed with spore-suspension on July 9th, and three with sterile water to serve as controls. Four of the six sprayed branches and five additional branches in plot A received a second application of spore-suspension on July 19th, but the remaining, two original branches received no further treatment. In plot E, all six branches received the second spray. The plots were visited daily and dead larvae were collected from the trays.

Diagnosis of dead larvae

Dead larvae were examined within 24 hours of the time of collection from the rearing globes or from the field. A permanent, stained slide was made from the body contents of each cadaver, and a sample of the body contents was plated on sterile nutrient agar in petri plates. A positive identification of the organism, Pr-1017, was usually possible after examining the slides and cultures. However, whenever there was doubt, the bacteria were subjected to biochemical analysis.

Results

Laboratory feeding tests

The results of the feeding tests conducted in the laboratory are recorded in Table I. The high incidence of mortality attributable to Pr-1017 in the laboratory, is believed to be influenced by the temperature, which was close to

TABLE I

Record of Laboratory feeding tests *Bacillus cereus* (Pr-1017)

Globe number:	Number of larvae tested:	Number of larvae dead:	Number of larvae killed by Pr-1017:	Percentage of larvae killed by Pr-1017:
1 to 15	225	159	148	65.8
Control	120	16	0	0
16 to 30	225	118	90	40.0
Control	30	0	0	0
31 to 41	165	118	87	52.7
Control	30	4	0	0

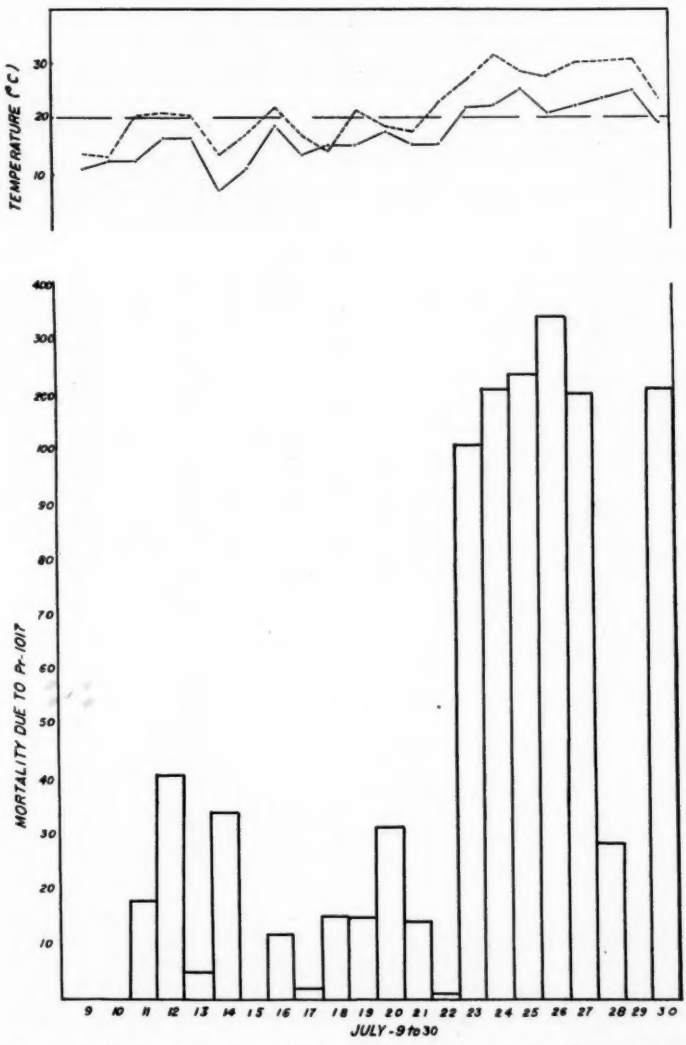

Figure 1. Daily record of larvae killed by Pr-1017 compared to the record of absolute maximum and daily mean temperatures for the general area. Dotted line—Daily maximum temperature. Solid line—Daily mean temperature.

27°C. during the experimental period. This point is discussed in a later section.

Field feeding tests

In plot A the incidence of mortality due to Pr-1017 ranged from 17 to 33 per cent and in plot E from 19 to 38 per cent of the total larvae per branch. Detailed results are recorded in Table II.

Discussion and Conclusions

The results of both the laboratory and field feeding tests prove that Pr-1017, a strain of *B. cereus*, is pathogenic for the larch sawfly.

TABLE II

Record of Larval Mortality due to Pr-1017 during the Experimental Period

Plot and Branch:	Total no. of larvae:	First Spray Mortality July 9th to 19th			Second Spray Mortality July 19th to 30th		
		Total dead:	Killed by Pr-1017:	% killed by Pr-1017:	Total dead:	Killed by Pr-1017:	% killed by Pr-1017:
A — *Received first spray only*							
2	287	24	16	5.6	64	51	17.8
5	256	7	5	2.0	63	56	21.9
Received second spray only							
10	280	—	—	—	97	90	32.1
11	295	—	—	—	105	91	30.9
12	279	—	—	—	112	92	33.0
13	221	—	—	—	83	74	33.5
14	280	—	—	—	99	91	32.5
Received first and second spray							
1	246	14	5	2.3	80	67	27.2
3	302	42	38	12.6	105	100	33.1
4	261	27	19	7.3	74	59	22.6
6	272	14	9	3.3	72	58	21.3
Controls							
7	290	76	0	0	52	0	0
8	286	15	1	0.4	24	3	1.1
9	226	2	0	0	20	0	0
E — *Received first and second sprays:*							
1	302	25	18	6.0	127	97	32.1
2	283	21	1	0.4	128	85	30.0
3	325	1	0	0	114	91	28.0
4	297	21	11	3.7	109	98	32.0
5	303	10	5	1.7	67	60	19.8
6	273	25	13	4.8	121	105	38.9
Controls							
7	298	7	1	0.3	12	1	0.3
8	265	30	1	0.4	41	4	1.5
9	293	8	0	0	9	0	0

Shortly after the second spray was applied in the field, the weather became considerably warmer. Until July 19th the mean temperatures, recorded daily, were consistently below 20°C. From July 23rd to the end of the month, the mean daily temperatures remained within the 'good growth' range for *B. cereus* (20 to 30°C.).

Figure 1 shows the daily maximum and the daily mean temperatures recorded in the general area of the field plots. The total incidence of mortality, due to Pr-1017, in plots A and E are included. There is a positive correlation between both the mean and maximum temperatures and the daily mortality ($r=0.935$; $P<.01$; d.f.19). A striking decrease in mortality caused by the bacterium, was noted whenever the mean daily temperature remained below 20°C. for an appreciable length of time. This same relationship was reported some 25 years ago by Metalnikov and Chorine (5).

This suggests that the low mortality after the first spray probably was a result of unfavourable temperatures. Branches II and V (see Table II) received only the first application of spray and the mortality recorded (17 to 22 per cent) is lower than average. This might indicate that the spores had been washed

off the branches by the time the favourable weather occurred, a period of thirteen days.

Further work on the organism and its potentialities as a control agent against the larch sawfly is planned.

Acknowledgments

I wish to thank Drs. M. L. Prebble, R. M. Belyea, A. S. West and G. W. K. Stehr, for their advice and co-operation. My thanks are also extended to Mr. W. R. Love for assistance with the field work.

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Abstract

A strain of *Bacillus cereus* (Pr-1017) was isolated from dead and dying larvae of the larch sawfly. Laboratory and field feeding tests resulted in mortalities as high as 60 per cent and 38 per cent, respectively.

A positive correlation between the incidence of mortality and the mean daily temperatures was obtained in the field experiments.

(Received August 26, 1953)

Erratum

The third paragraph on page 128 of Vol. 85 (No. 4) should begin as follows:

***Choristoneura fumiferana* (Clem.)**

Second Instar.—Average head length: 0.26 mm.; average head width: 0.32 mm.; average length of median dorsal line from anterior edge of postclypeus to termination of adfrontal sutures: 0.203 mm.; average width of postclypeus: 0.15 mm.

Distinct Morphological Differences Between DDT-Resistant and Non-DDT-Resistant Strains of the House Fly, *Musca domestica* L.[1]

By R. S. BIGELOW[2] AND E. J. LEROUX[3]

This paper is a report on the discovery of distinct morphological differences between DDT-resistant and non-DDT-resistant strains of the house fly, *Musca domestica* L. Since DDT-resistant house flies were first reported in Italy in 1945-46, such differences have been sought by a number of workers (e.g. Wiesmann, 1947; D'Alessandro *et al.*, 1949; March and Lewallen, 1950; Anon., 1950). Various slight differences have been detected but none of a magnitude comparable to those described in this paper has so far been reported.

Most workers have sought differences in structural characters that could be directly related to the absorption of DDT; for example, in the structure of the integument, size of pulvilli, tarsal segments, etc. However, since it is an established fact of genetics that physiological characters may be genetically associated (through linkage or pleiotropic effects of certain genes) with morphological characters without apparent functional correlation existing between them, this study was conducted from the point of view that any morphological differences might be genetically associated with the factors producing DDT-resistance.

The house fly strains first compared were: (1) a DDT-resistant (Beltsville) strain that had been reared for many generations in DDT-painted cages (kindly supplied by Drs. R. W. Fisher and B. N. Smallman, Science Service Laboratory, London, Ontario), and (2) a non-DDT-resistant (Macdonald) strain that had been reared for three years in a DDT-free environment at Macdonald College, Quebec.

Several morphological differences were detected and the following four characters were measured in each strain: (1) maximum width of second abdominal sternum (X_1); (2) maximum length of second abdominal sternum (X_2) (Figs. 1 & 2); (3) width of frons between the ptilinal sutures at the level of the boundary between the second and third antennal segments (X_3) (Fig. 3); and length of terminal segment of right antenna measured along the anterior surface (X_4) (Fig. 3). Each character was measured independently by each author. In no case was the standard deviation corresponding to the error of measurement greater than ± 0.01 mm.

Since the intra-strain variances for X_1, X_2, and X_3 were of the same order for both strains, they were pooled for each character. The sample sizes (N), means ($\bar{X}_m$, $\bar{X}_b$), standard deviations (s), and t values appropriate for testing the mean differences (t) were:

Character	N	$\bar{X}_m$(mm.)	$\bar{X}_b$(mm.)	s(mm.)	t
X_1	450	0.528	0.690	0.05	34.2
X_2	225	0.578	0.576	0.04	0.4
X_3	325	0.550	0.629	0.04	18.3

These t values indicate that the mean length of the second abdominal sternum was of the same order in both strains, but that the means of X_1 and X_3 differed

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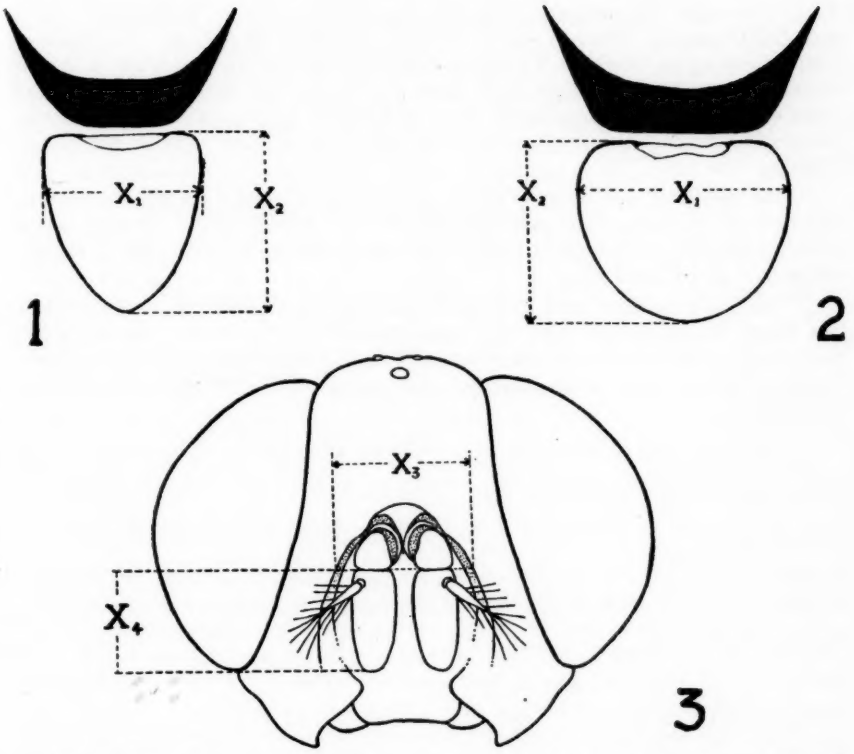

Fig. 1. First and second abdominal sterna drawn to scale from the average condition in the Macdonald strain.

Fig. 2. First and second abdominal sterna drawn to scale from the average condition in the Beltsville strain.

Fig. 3. Anterior aspect of the face (female, not drawn to scale).

markedly between strains. The *t* value listed in tables of the normal probability integral at the 0.001 level of significance for each character was 3.3.

Assuming that the samples used are representative, it can be stated with 99.9% confidence that the true difference in X_1, between the Macdonald and the Beltsville strains, is greater than 0.146 mm. The second abdominal sternum would be wider than 0.609 mm. in 95% of the individual specimens of the Beltsville strain, and narrower than this in 95% of the individuals of the Macdonald strain. The width of the frons would be greater than 0.590 mm. in 85% of the individual specimens of the Beltsville strain, and less than this in 85% of the individuals of the Macdonald strain.

Since the strains differ so distinctly in these two characters, the possibility that one or both might be genetically associated with the factors producing DDT-resistance cannot be overlooked. With this in mind, the Macdonald and the Beltsville strains were compared with the following strains of house flies: (1) a DDT-and-lindane-resistant (Super Pollard) strain; (2) a DDT-resistant (Super Bellflower) strain; (3) a methoxychlor resistant (Methoxychlor) strain; (4) a non-DDT-resistant (California) laboratory strain (all kindly supplied by Dr.

L. L. Lewallen, Department of Entomology, University of California); (5) a non-DDT-resistant (Mayo) strain (kindly supplied by Mr. W. S. Macleod, Officer-in-Charge, Pesticide Testing Laboratory, Ottawa, Ontario); (6) a Wilson strain that was DDT-resistant eight years ago but has not been exposed to DDT since that time (kindly supplied by Dr. E. J. Hansens, Department of Entomology, Rutgers University); and (7) with wild flies from a dairy barn at Macdonald College.

Due to overall size differences between strains, X_1 and X_2 were combined in the ratio $X_1/X_2=X_5$. This ratio was measured in 25 males and 25 females of the wild population, in 15 females of the Mayo strain and in 15 males and 15 females of each of the other strains.

The DDT-resistant and non-DDT-resistant strains differed consistently in the shape of the second abdominal sternum, which was on the average wider than long in the DDT-resistant strains and longer than wide in the non-DDT-resistant strains. The corresponding strain means ($\overline{X}_5$), and standard deviations (s) were:

Strain	$\overline{X}_5$	s
Beltsville	1.207	±0.10
Pollard	1.079	±0.09
Bellflower	1.037	±0.08
Methoxychlor	0.962	±0.08
Mayo	0.946	±0.06
California	0.932	±0.07
Macdonald	0.925	±0.07
Wild	0.910	±0.06
Wilson	0.906	±0.05

The t values corresponding to the mean differences in X_5, between the Bellflower strain and the Methoxychlor and Mayo strains, were 3.55 and 4.25 respectively. The t values listed in the tables of the normal probability integral for the appropriate degrees of freedom are: 2.67 at the 5% level, and 3.67 at the 1% level of significance. This indicates that the mean ratios of width to length of the second abdominal sterna differ markedly between even the most similar strains from the DDT-resistant and non-DDT-resistant groups. The Wilson strain is here considered as non-DDT-resistant since there is ample evidence that reversion to the non-DDT-resistant state takes place in 10 to 15 generations in some strains reared in the absence of DDT (Barber and Schmitt, 1949; King, 1950; Babers and Pratt, 1951; Crow, 1952). The degree of DDT-resistance that may have existed in the wild flies is unknown. They are considered as non-DDT-resistant here.

These differences can be seen clearly in Fig 4, in which the strain mean is indicated by the arrow, and the deviation corresponding to three times the standard error of the mean by the horizontal line in each case.

If the samples used are representative, the strain means of random samples of 30 flies can be expected to fall outside the limits indicated by the horizontal

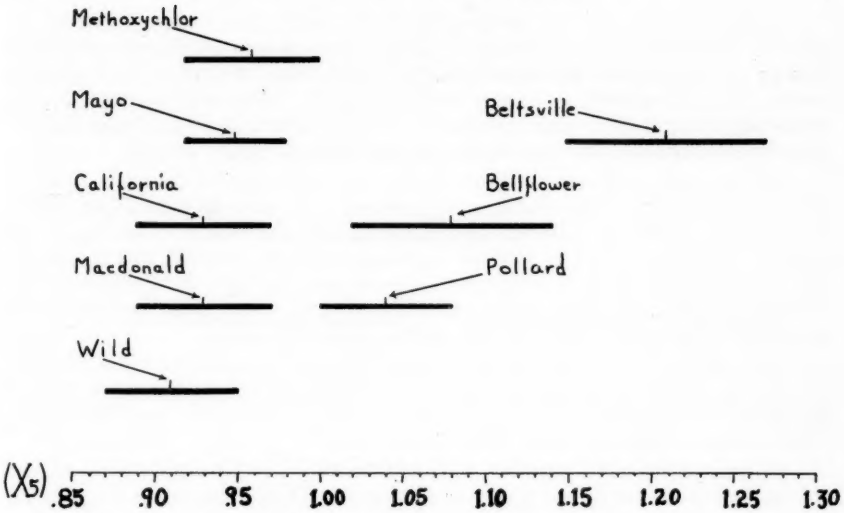

Fig. 4. Strain means and 3 times standard error of means for X_5.

lines less than once in a hundred times by chance alone.* There is no overlapping of these limits between the DDT-resistant and non-DDT-resistant strains. Therefore, using the mean X_5 of samples of 30 (50 in the case of the wild flies), flies from any of these strains could be correctly classified as DDT-resistant or non-DDT-resistant with a precision, for all practical purposes, of 100%.

The following analysis of variance was applied to the Beltsville, Pollard, Bellflower, Methoxychlor, California, and Macdonald strains, using samples of 15 males and 15 females from each strain:

*For the Mayo strain and the wild flies the appropriate sample sizes are 15 and 50 respectively.

TABLE I

X_5. Analysis of Variance.

Source	*d.f.*	*S.S.*	*M.S.*	*F.*
SAMPLES	11	1.8324	0.1666	23.80**
STRAINS	5	1.7386	0.3477	49.67**
R vs non-R	1	1.2265	1.2265	117.52**
Between R	2	0.4894	0.2447	34.96**
Methox. vs non-R	1	0.0221	0.0221	3.16
Between non-R	1	0.0006	0.0006	0.09
STRAINS x SEX	5	0.0833	0.0167	2.39*
Sex x (R vs non-R)	1	0.0070	0.0070	1.00
Sex x (Between R)	2	0.0751	0.0376	5.37**
Sex x (Methox. vs non-R)	1	0.0004	0.0004	0.06
Sex x (Between non-R)	1	0.0008	0.0008	0.11
SEX	1	0.0105	0.0105	1.50
TOTAL S.S.	179	3.0006	0.0168	2.40**
ERROR	168	1.1682	0.0070	

**Significant at 1% level.
*Significant at 5% level.

Table 1 shows that the strains differed markedly from one another in X_5; that the difference between the DDT-resistant and the non-DDT-resistant groups formed the major part of the overall differences; that the three DDT-resistant strains differed markedly from one another; that the Methoxychlor strain did not differ significantly from the Macdonald and the California strains; and that the Macdonald and the California strains did not differ from one another.

Table 1 shows also that the sex differences were not of the same order in all strains. The mean differences in X_5 between sexes were subjected individually to *t*-tests in all strains. These *t*-tests revealed that the mean X_5 for males and females differed at the 5% level of significance in the Pollard and Bellflower strains but did not differ in any of the other strains. In both the Pollard and the Bellflower strains the mean X_5 for males was slightly more similar to that of the non-DDT-resistant flies than was the mean X_5 for the females.

The ratios of the length of the terminal antennal segment to width of frons ($X_4/X_3=X_6$) were measured in samples of 15 males and 15 females from each of the Beltsville, Pollard, Bellflower, Methoxychlor, California, and Macdonald strains and in 15 females of the Mayo strain.

Distinct differences existed between the sexes, but the within sex variance was of the same order for both sexes in each strain. Therefore, the corresponding strain means ($\bar{X}_6$) are listed separately, and the standard deviations (s) are pooled for both sexes as follows:

Strain	Females	Males	s
Beltsville	0.630	0.689	±0.06
Bellflower	0.670	0.749	±0.08
Pollard	0.670	0.742	±0.05
California	0.730	0.776	±0.04
Macdonald	0.736	0.783	±0.07
Methoxychlor	0.750	0.815	±0.05
Mayo	0.763	—	±0.03

Comparison of the mean differences in X_6 by *t*-tests revealed that: (1) in the females, the mean difference between the Bellflower and Macdonald strains was significant at the 5% level; all other mean differences between the DDT-resistant and the non-DDT-resistant strains were significant at the 1% level; (2) in the males, the mean X_6 was of the same order in the Bellflower, Macdonald, and California strains; the Pollard strain differed from the Macdonald and California strains at the 5% level; the Beltsville strain differed from the non-DDT-resistant strains at the 1% level, and from the Bellflower and Pollard strains at the 5% level of significance. The Methoxychlor strain did not differ from the Macdonald or California strains, but differed markedly from all the DDT-resistant strains.

The strain means and the deviations corresponding to three times the standard errors of the means are shown, for females, in figure 5.

The following analysis of variance was applied to samples of 15 females from each of the Beltsville, Pollard, Bellflower, Methoxychlor, California, and Macdonald strains:

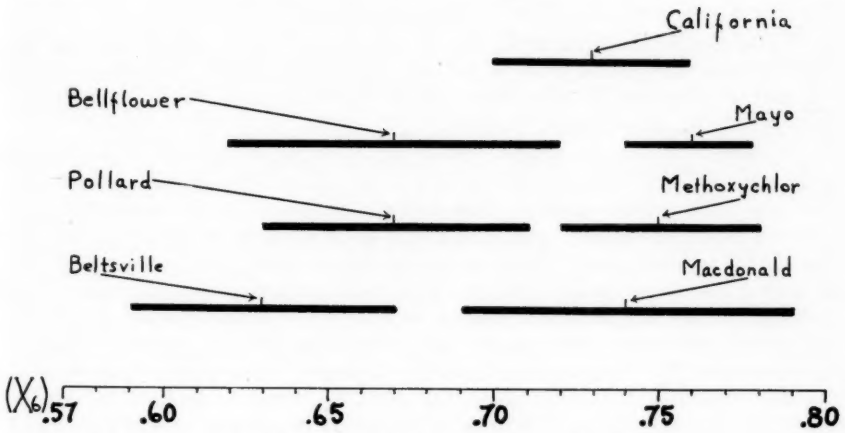

Fig. 5. Strain means and 3 times standard error of means for X_6.

TABLE II

X_6. Analysis of Variance.

Source	*d.f.*	*S.S.*	*M.S.*	*F.*
SAMPLES	11	0.4932	0.0448	12.80**
STRAINS	5	0.3256	0.0651	18.60**
R vs non-R	1	0.2536	0.2536	72.46**
Between R	2	0.0573	0.0287	8.20**
Methox. vs non-R	1	0.0140	0.0140	4.00
Between non-R	1	0.0006	0.0006	0.17
STRAINS x SEX	5	0.0076	0.0015	0.43
SEX	1	0.1600	0.1600	45.71**
TOTAL S.S.	179	1.0835	0.0061	1.74*
ERROR	168	0.5903	0.0035	

Table 2 shows that the strains differed markedly from one another in X_6; that the differences between the DDT-resistant and the non-DDT-resistant groups formed the major part of the overall differences; that the three DDT-resistant strains differed markedly from one another; that the Methoxychlor strain differed from the Macdonald and California strains at the 5% level of significance; and that the Macdonald and California strains did not differ from one another. The Methoxychlor strain differed from the DDT-resistant strains more markedly in X_6 than did either the Macdonald or the California strains (this difference was greater in males than in females).

Table 2 shows also that the sexes differed markedly, and that these sex differences were of the same order in all six strains. The difference in X_6 between sexes is probably derived largely from the normal tendency for the eyes to be less widely separated in the males than in the females.

The calculation of analysis of variance is outlined in chapter five of Goulden (1952).

Discussion

The distinct similarity in X_5 and X_6 between all the non-DDT-resistant flies, whether their origin was Quebec or California, eliminates the possibility that the consistent differences between them and the DDT-resistant flies, in these characters, are due to geographical variation.

Despite differences between them, all three DDT-resistant strains shared similarities in X_5 and X_6 that clearly placed them in a single group, distinct from the non-DDT-resistant group. This strongly suggests that the similarities were derived from a common origin, and that their common difference from the non-DDT-resistant group did not occur by chance alone. It appears certain that at least a part of the genetic factors involved in producing the differences in X_5 and X_6, that set off the DDT-resistant from the non-DDT-resistant groups, are genetically associated with the factors producing DDT-resistance. There is evidence that DDT-resistance in house flies probably has a complex genetic basis, i.e. that a number of different genes are involved (Harrison, 1953; Crow, 1952).

The Beltsville strain differs more distinctly from the non-DDT-resistant group, in both X_5 and X_6, than do the Bellflower and Pollard strains. This suggests that the Beltsville strain possesses more of the genetic factors involved in producing the X_5 and X_6 differences than do the other two DDT-resistant strains. This does not force the conclusion that the Beltsville strain is therefore more resistant to DDT, since it is highly probable that a number of the DDT-resistant factors are not genetically associated with X_5 and X_6 differences. For example, if the Beltsville strain possessed all the genetic factors that produce both the X_5 and X_6 differences and DDT-resistance, but only a few of those producing only DDT-resistance, and if the other two strains possessed all the factors producing only DDT-resistance and only a part of those producing the X_5 and the X_6 differences, then the Beltsville strain could be least resistant to DDT and at the same time differ most in these characters from the normal condition. It is highly probable also that some of the genetic factors involved in DDT-resistance produce a greater degree of resistance than do others. Some of these may not be associated with the X_5 and X_6 differences. DDT-resistant strains may exist that show little or none of these differences from the normal condition, yet the genetic association between these differences and DDT-resistance would continue to be obvious in the Beltsville, Pollard, and Bellflower strains.,

Consideration of both X_5 and X_6 is likely to involve a greater proportion of the genetic factors producing DDT-resistance than is the consideration of either one alone. With this in mind, two combinations of the characters measured were expressed in linear discriminant functions. X_1, X_2 and X_3 gave the following function relative to the Beltsville and Macdonald strains:

$$Z = 1.89\,X_1 - X_2 + 2.19\,X_3$$
$$(\text{Critical } Z = 1.925)$$

The discriminating precision of this function, applied to individual specimens of one or the other of the two strains, was 98%, which was greater than that obtained from any one character alone (i.e. 95% for X_1, 85% for X_3).

X_5 and X_6 were combined in a function based on random samples of five female specimens from each of the Beltsville, Pollard, Bellflower, California, Macdonald, and Mayo strains; i.e. samples of 15 resistant and 15 non-resistant specimens. This function was:

$$Z = X_5 - 3.07\,X_6$$
$$(\text{Critical } Z = -1.060)$$

In this case the discriminating precision for individual female specimens was 90%, as compared with 76% for X_5, and 85% for X_6. Using samples of 15 females, the discriminating precision of either of these functions is practically 100%, and greater than that to be expected from any one character alone. In the case of the function involving X_1, X_2 and X_3 either males or females could be used. This supports the evidence of Bigelow and Reimer (1954). Furthermore the function is likely to involve a greater proportion of the genetic factors producing DDT-resistance, in that it combines more than one morphological character.

Although DDT-resistance as it exists in the Beltsville, Pollard, or Bellflower strains could be detected from samples of 30 flies with practically 100% precision by using either X_5 or the discriminant function combining X_5 and X_6, the detection of lesser degrees of resistance, with these characters alone, might not be possible. However, the morphological differences discussed in this paper are not the only morphological differences that exist between the DDT-resistant and non-DDT-resistant groups. The third and fourth abdominal sterna are also noticeably wider relative to their length in the resistant strains. A thorough combing might reveal a complex of morphological differences that would involve the major portion of the genetic factors producing DDT-resistance. Such a complex, combined in a discriminant function, could provide an accurate criterion for the detection of relatively slight degrees of DDT-resistance.

Conclusions

It is reasonable to conclude from the results presented in this paper that (1) distinct morphological differences exist between DDT-resistant and non-DDT-resistant strains of the house fly; (2) two of these differences are genetically associated with the factors producing DDT-resistance; (3) several such differences can be combined in a linear discriminant function that will give greater discriminating precision than will any one character alone, and will probably also involve a greater proportion of the genetic factors producing DDT-resistance; (4) the use of such a discriminant function might prove to be an accurate method of detecting DDT-resistance in wild house fly populations; and (5) genetic association between morphological characters and resistance to insecticides probably exists in insects other than the house fly.

Acknowledgments

The authors wish to express their thanks to Professors E. M. DuPorte, F. O. Morrison, H. A. Steppler, and R. I. Brawn of Macdonald College, Que., and to Dr. H. H. J. Nesbitt, Carleton College, Ottawa, W. A. Ross, and C. Reimer of Science Service, Department of Agriculture, Ottawa, for valuable assistance and advice.

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(Received January 29, 1954)

The *Prunus- and Rubus*-Feeding Species of *Macropsis* (Homoptera: Cicadellidae)[1]

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It is important that the species of leafhoppers of the genus *Macropsis* that feed on fruit trees should be readily identifiable, as at least one of them transmits the plant virus that produces the symptoms known as peach yellows and little peach. There has been some confusion between the *Prunus*-feeding species because it is frequently not possible to name adult specimens on external characters alone, and the male genitalia, which usually provide reliable specific characters, have not been illustrated or adequately described. Moreover, there is a form in this group whose status, as a species or as a variety, has been uncertain; and there is established in British Columbia a *Rubus*-feeding species that has not been recorded previously from North America.

Key to Species

1. Each hind tibia with a prominent black spot near base (Fig. 22); host plants, *Rubus* spp. ..... *fuscula* (Zett.)
   Hind tibiae not spotted; host plants, *Prunus* spp. 2
2. Lower part of face with a large, rounded, black or brownish blotch, upper part with an irregular, black or brownish, transverse band below margin of vertex (Fig. 24); forewing usually with veins margined with brownish or fuscous dots contrasting with the paler ground colour (Fig. 27); larger species, 4.75-5.5 mm. in length ..... *tristis* (van D.)
   Face not marked as above, wholly pale or more or less suffused fuscous; forewing not as above, sometimes with veins paler than ground colour and often with whitish areas; usually smaller species, 5 mm. or less in length 3
3. Aedoeagus long, slender, strongly curved, and forked at apex (Fig. 5); forewing with one or no whitish spot, and in female often with veins contrastingly paler than ground colour (Fig. 29) ..... *insignis* (van D.)
   Aedoeagus short, stout, and less strongly curved; forewing usually with two or three pellucid spots and with veins usually concolorous with ground colour 4
4. Apical region of aedoeagus flattened and flaringly expanded in dorsal view (Figs. 9-14); general colour light greyish-fuscous to blackish-fuscous; forewing usually with three pellucid spots (Fig. 28); larger species, 4.25-5.0 mm. in length ..... *trimaculata* (Fitch)
   Aedoeagus not as above, with apical region scarcely expanded in dorsal view (Fig. 7); general colour reddish-brown; forewing usually with two whitish spots (Fig. 26); smaller species, 4.0-4.5 mm. in length ..... *quadrimaculata* Breakey

Macropsis fuscula (Zett.)

Figs. 1, 6, 17, 22, 23, 25

Jassus fruiticola var. f. [*fusculus*] Zetterstedt, 1840: 303.
Jassus rubi Boheman, 1845: 54.
Pediopsis tibialis Scott, 1874: 195.

Length 4.5-5.0 mm. The female is greyish-yellow, marked black as follows: face with a rounded spot below each ocellus, a smaller spot below each of these, and the sides of the clypeus margined black; pronotum with two pairs of large,

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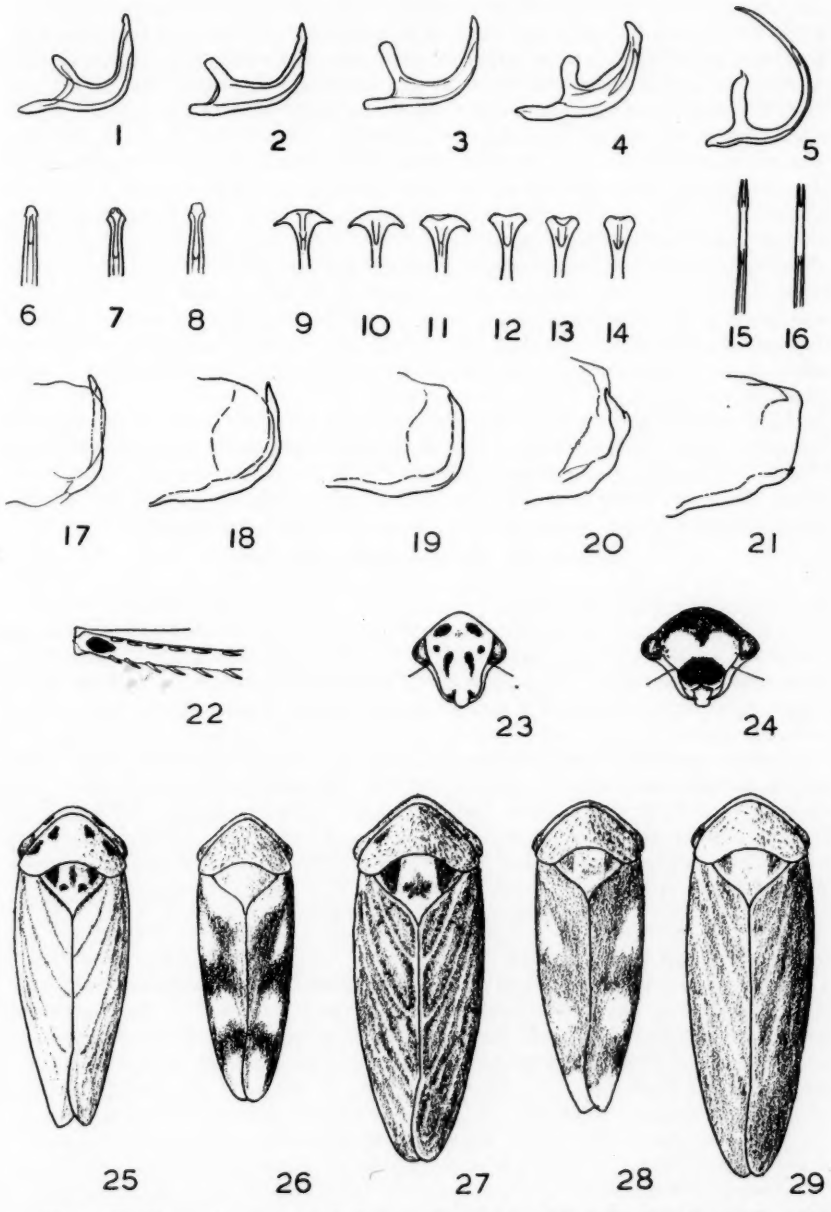

Figs. 1-29, *Macropsis* spp. 1-5, Aedoeagus, lateral view, of: 1, *M. fuscula*; 2, *M. quadrimaculata*; 3, *M. tristis*; 4, *M. trimaculata*; 5, *M. insignis*. 6-16, Apical region of aedoeagus, dorsal view, of: 6, *M. fuscula*; 7, *M. quadrimaculata*; 8, *M. tristis*; 9-14, *M. trimaculata*; 15, 16, *M. insignis*. 17-21, Apical region of pygofer of: 17, *M. fuscula;* 18, *M. quadrimaculata*; 19, *M. tristis*; 20, *M. trimaculata*; 21, *M. insignis*. 22, Hind tibia of *M. fuscula*. 23, 24, Head, from the front, of: 23, *M. fuscula*; 24, *M. tristis*. 25-29, Adult female of: 25, *M. fuscula*; 26, *M. quadrimaculata;* 27, *M. tristis;* 28, *M. trimaculata*; 29, *insignis*.

irregular spots, often more or less confluent, near the anterior margin; forewings with veins brownish-black; and hind tibiae each with a prominent spot near base. The body of the male is more brownish than that of the female, the forewings are darker, the dark markings of the head and pronotum are better developed, and there is usually a median spot on the face below the margin of the vertex. There is variation in colour and markings in both sexes. Any of the black spots other than those of the tibiae may be reduced or absent, the veins of the forewing may not be darker than the ground colour, and there may be additional dark markings on the legs. The variety *tibialis* has the uppermost pair of facial spots comma-shaped and often confluent medially.

The black-spotted tibiae together with the facial spots distinguish this from other North American species of *Macropsis*. Black-spotted hind tibiae are characteristic of European species, and all North American species that have them are introductions from Europe. Other North American species that have black-spotted tibiae may be readily distinguished from *fuscula* by the absence of dark facial spots and by the host plants.

This species has not been recorded previously from North America. It is evidently established in British Columbia. Fifty specimens were collected by Mr. N. V. Tonks, Entomology Laboratory, Victoria, on loganberry at Lulu Island, British Columbia, on July 18, 1952. The species is common and widely distributed in Europe, where it feeds on various species of *Rubus*.

***Macropsis quadrimaculata* Breakey**

Figs. 2, 7, 18, 26

Macropsis quadrimaculata Breakey, 1932: 832.

This species may be readily distinguished from *trimaculata* and *insignis* by characters of the male genitalia, and from those and the other species under discussion by the colour and markings. The general colour is reddish-brown or yellowish-brown, whereas the remaining species are brownish or fuscous and lack the reddish tinge.

This is apparently the most rare and local species of the group. It has been recorded from localities in South Dakota, Nebraska, North Carolina, and Tennessee, and specimens from Colorado have been examined. According to Breakey (1932), the holotype and allotype bear labels indicating that they were collected on raspberry (*Rubus* sp.), but Turner (1946) collected the species only on wild plum.

***Macropsis tristis* (van D.)**

Figs. 3, 8, 19, 24, 27

Pediopsis tristis van Duzee, 1890: 249.

This species resembles *fuscula* and *quadrimaculata* in genitalic characters. It may be distinguished from the former by the host-plant and by the absence of black spots on the tibiae, and from the latter by the presence of black facial markings. The general colour is fuscous or greyish-fuscous. Distinctive characters are the black facial markings described in the key, the relatively large size, and, at least in the female, the dark-margined veins of the forewing.

This is a widely distributed species in the east-central and northeastern parts of the United States. The distribution is similar to that of *insignis* and *trimaculata* (see Turner, 1946), and, like those species with which it often occurs in mixed colonies, it feeds on plum (*Prunus* spp.).

***Macropsis trimaculata* (Fitch)**

Figs. 4, 9-14, 20, 28

Pediopsis trimaculata Fitch, 1851: 60.

The form of the aedoeagus distinguishes this from other species of *Macropsis*. There is variation in the form of the expanded apical region of the aedoeagus:

in some specimens that region curves outward and downward to a point at each side (Figs. 9, 10); in others it is truncate at each side (Figs. 12-14). The latter is the anomalous form mentioned by Turner (1946) as either a new species or a variety of *trimaculata*. Examination of the male genitalia of a number of specimens indicates that specimens of this form are normal ones of *trimaculata* in which the lateral processes of the apical expansion of the aedoeagus have been broken off. In some instances both forms of aedoeagus were found in specimens collected at the same time. A specimen in which only one side of the aedoeagus is broken off is shown in Fig. 11. It is possible that the damage to the aedoeagus occurs during mating: specimens with the damaged aedoeagus were mostly collected late in July and in August, whereas specimens with the normal aedoeagus were mostly collected in June and early in July.

The female is sometimes difficult to distinguish from those of allied species because of the individual variation. The general colour and the size distinguish it from *quadrimaculata* (see key); the lack of definite dark facial markings distinguishes it from *tristis*; the three pellucid areas on the forewing distinguish it from *insignis*, which has one or no such area. The male is often heavily marked blackish underneath and the ground colour of the forewings is usually darker so that the pellucid areas are usually better defined than in the female. Newly emerged specimens of both sexes are feebly pruinose.

This is a common and widely distributed species in the east-central and northeastern areas of the United States and in Eastern Canada from southern Ontario to Nova Scotia. It feeds on plum (*Prunus* spp.) and often occurs in mixed populations with other plum-feeding species. The life-history was described by Hartzell (1937). This is the species that Kunkel (1933) and Manns and Manns (1934) showed to be capable of transmitting peach yellows and little peach. However, because of the difficulty in naming living specimens accurately and because several species commonly occur together as mixed populations, additional species may be involved. Peach is not a host plant, but the adult of *trimaculata*, like many species of leafhoppers, feeds casually on plants other than its host, including peach, apricot, and grapes. These casual feeders transmit the plant virus from plum to peach.

***Macropsis insignis* (van D.)**

Figs. 5, 15, 16, 21, 29

Pediopsis insignis van Duzee, 1889: 171.

The form of the aedoeagus distinguishes this from other species of *Macropsis*. The female is often difficult to separate from those of allied species, notably *trimaculata*, because of the variation in colour and markings. The absence of obvious pellucid areas on the forewings and the yellow veins contrasting with the darker ground colour tend to be distinctive in the female, though these characters are not always reliable. Freshly emerged specimens of both sexes are distinctly pruinose, and as a result have a general greyish- or whitish-brown appearance.

This is a common and widely distributed species in the east-central and northeastern areas of the United States and in Eastern Canada. The host plant is plum (*Prunus* spp.).

Acknowledgments

The writer wishes to thank Mr. J. H. H. Phillips and Mr. W. L. Putman, Entomology Laboratory, Vineland Station, Ontario, and Mr. N. V. Tonks, Entomology Laboratory, Victoria, British Columbia, for sending specimens for examination, and Dr. David A. Young, Bureau of Entomology and Plant Quar-

antine, United States Department of Agriculture, for the loan of specimens from the United States National Museum.

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(Received August 25, 1953)

Biological Evidence of Sibling Species in *Aphytis maculicornis* (Masi). (Hymenoptera, Aphelinidae)

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In biological control work an early taxonomic identification of imported entomophagous species is helpful but not essential, for in this applied field of entomology the behaviour and biological characteristics of species are held paramount to their taxonomic status. In actual practice it frequently happens that a species is imported, tested, colonized, and established before its specific taxonomic identity is conclusively determined. Examples exist in recent literature where one may find references to such insects designated as "*Aphytis* X", "Waikane *Opius*", etc. While this situation is not altogether comfortable to the worker in biological control it arises as a natural consequence of the initial and necessary concentration on the ecological and biological aspects of insect groups. It is particularly intensified by the fact that many parasitic groups are still poorly understood taxonomically.

During 1951 a quarantine unit designed to handle the safe importation of beneficial insects was constructed at Albany, California, by the University of California (Doutt, 1951). Upon completion it was immediately put into operation to receive and process shipments of *Parlatoria oleae* (Colvée) which were being collected by Dr. A. M. Boyce in India, Pakistan, Afghanistan, Iran, Iraq, Cyprus, Syria, Lebanon, Israel, and Spain. The procedure adopted at the outset was to treat the parasites emerging from *Parlatoria* as distinct biological entities even though morphologically indistinguishable from species extant in California. Material of similar appearance but from different areas was also cultured separately until preliminary observations of a comparative nature had been completed. This policy led to the discovery of certain *Aphytis* which morpho-

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logically resemble the species *maculicornis* (Masi) but which are distinctly different biologically.

Since these biologically different *Aphytis* are morphologically identical, apparently allopatric, and reproductively isolated they fit the category of sibling species according to the "discrimination grid" of Mayr, Linsley, and Usinger (1953). These authors describe this category as follows: "Sibling species are not a different type of species; they are merely those species that are near the invisible end of the spectrum of morphological species differences. They grade imperceptibly into species that are morphologically more and more distinct from one another. Morphological differences are often eventually found after a particularly painstaking scouting of previously unstudied structures."

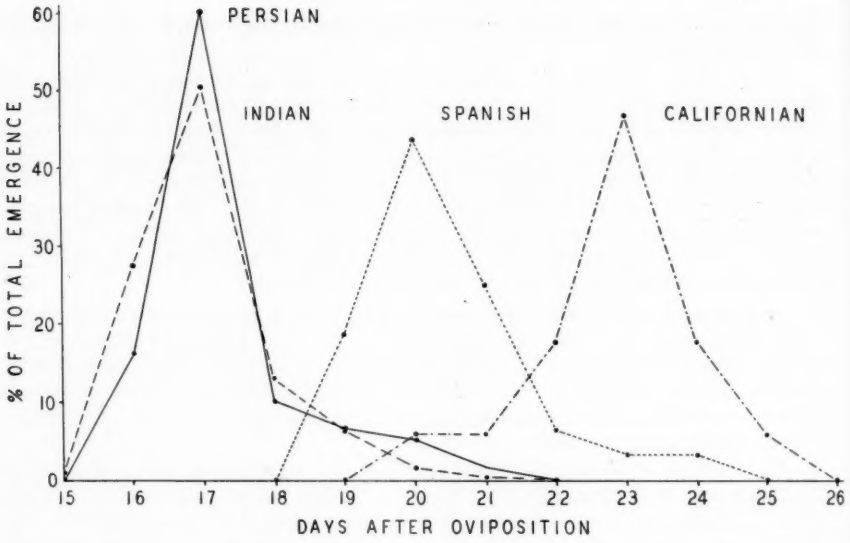
It is quite possible that some morphological character may exist by which these different *Aphytis* may be separated, but if so it is very cryptic and has escaped disclosure by the use of all the modern techniques for the examination of parasitic Hymenoptera in the hands of several specialists. The biological differences, on the other hand, are clear cut and this paper is largely an account of their quantitative expression.

On the basis of early differences noted in quarantine the cultures of *Aphytis* were separated into three distinct categories. These were designated as (1) the Indian *Aphytis* which was obtained from stock collected in India, Pakistan, and Afghanistan; (2) the Persian *Aphytis* originating in material sent from Iraq and Iran; (3) the Spanish *Aphytis* bred from the scale collected in Spain. In addition a fourth group was uncovered by culturing an indigenous *Aphytis* obtained from *Parlatoria* in the San Joaquin Valley of California. This fourth type has been designated as the Californian *Aphytis*. For comparative studies in the laboratory all four types of these parasites were cultured on the latania scale, *Hemiberlesia lataniae* (Signoret), which was grown on potato tubers. Five to six week-old latania scale gave best results as host insects and the cultures were maintained in an insectary at 82°F. and 65 R.H. Intensive comparative studies were begun in 1952 and the results are reported herein.

Duration of developmental stages:—In order to determine the exact duration of each developmental stage in each of the four *Aphytis* strains, the following method was used: four potato tubers infested with 37-41 day-old host scale were exposed singly and simultaneously, each to a separate *Aphytis* strain for six hours. Then the parasites were removed and the tubers carrying the parasitized hosts were kept singly in small jars. Daily dissections were made of host samples from each jar to determine the developmental stage of the parasites. This daily examination was continued until all strains had reached the pupal stage. Then records were kept of the number of parasites emerging each day. The results are presented in Tables 1 and 2 and Graph 1.

These results, presented here both graphically and in tabular form, show the following: (1) An incubation period of three days occurs in all strains except in the Californian which remains in the egg stage 4-5 days. (2) The larvae of the Persian and Indian strains develop faster than those of the Spanish and Californian *Aphytis;* the same condition is true of the pupae. (3) The day of peak emergence may be an important criterion for separating these *Aphytis* biologically, and it should also be of practical importance as an indication of the voltinism of each strain.[3] The Indian and Persian cultures emerged in greatest numbers 17 days after oviposition, whereas the Spanish required 20 days, and the greatest proportion of the Californian strain did not emerge until 23 days after oviposition. (4) Three significantly different groups, (a) the Persian and Indian, (b) the Spanish,

[3]It was noticed that the parasites which emerged in the period after the peak emergence were comparatively smaller and weaker than the earlier appearing individuals.



Graph 1. Emergence patterns of four strains of *Aphytis maculicornis*.

and (c) the Californian are clearly indicated by this study on duration of developmental stages.

Sex Ratio:—One of the striking differences between the sibling species in the *Aphytis maculicornis* complex is the fact that two are thelyotokous and one, at least, is arrhenotokous. The sex ratio of the four types of *Aphytis* were carefully checked and are shown in Table 3.

These data disclose three salient facts: (1) The Persian and Indian *Aphytis* are arrhenotokous and these bisexual *Aphytis* have a tendency to produce more females than males, for the Persian population consisted of 63.3% females and the Indian consisted of 67.5% females. (2) The female sex is highly dominant in the Spanish strain for 99.3% of the sampled population were of this sex. (3) The Californian strain is apparently completely thelyotokous for not a single male has been found.

TABLE I

Duration of developmental stages in four strains of *Aphytis maculicornis*

Developmental stage	Time in Days			
	Persian	Indian	Spanish	Californian
Incubation period	3	3	3	4–5
Larval period	7–9	7–9	8–10	8–10
Pupal period	6–9	5–9	8–11	8–10
Total life cycle	16–21	15–21	19–24	20–25
Day of peak of emergence	17	17	20	23

TABLE II
Emergence pattern of adult parasites

Days after oviposition	Percentage of emerging parasites			
	Persian	Indian	Spanish	Californian
15	0	.7	0	0
16	16.1	27.7	0	0
17	60.2	50.3	0	0
18	10.2	12.9	0	0
19	6.8	6.5	18.7	0
20	5.1	1.5	43.8	5.9
21	1.6	.4	25.0	5.9
22	0	0	6.3	17.7
23	0	0	3.1	46.9
24	0	0	3.1	17.7
25	0	0	0	5.9
Total	100.0	100.0	100.0	100.0

Unmated females of both the Spanish and Californian strains which had been isolated in the pupal stage gave rise to female progeny exclusively, whereas unmated females of the Persian and Indian types produced males only.

In the laboratory cultures it was noticed that a single mating is insufficient to provide a female with enough sperm to last throughout her life span. When repeated matings are not accomplished the percentage of females in the progeny falls until a point is reached where the population is entirely male.

Longevity of Adults:—Experiments have been conducted to determine the longevity of the adults of the four strains under different conditions. From experiments carried out in the insectary, in an outside weather shelter during April and May, and in a refrigerator at 35°F. no significant difference was found in the adult longevity of the four strains (see Table 5).

The average longevity of the males is shorter than that of the females, particularly in the field where the difference was 9-10 days as compared to a difference of 2 days in the insectary. All adults of both sexes died in less than 24 hours when kept in a refrigerator at 35°F.

Number of progeny per female:—To determine the reproductive capacity of the separate components of this *Aphytis* complex twenty-five females of each strain (twenty females only in case of the Californian strain) were isolated individually in the pupal stage. Upon emergence as an adult each female was confined in a small jar, together with one male in the case of the Persian and Indian strains. A potato tuber infested with suitable hosts was introduced into the jar and replaced twice each week until the female parasite died. The removed potato tubers, bearing the now-parasitized hosts, were kept singly in separate jars and the emerging parasites were counted and sexed. By this procedure the

TABLE III

Sex ratios in four strains of *Aphytis maculicornis*

Strain of *Aphytis*	No. of adults checked	No. of females	No. of males	Percentage of females in population
Persian	1152	729	423	63.3
Indian	1255	847	408	67.5
Spanish	1749	1737	12	99.3
Californian	671	671	0	100.0

entire progeny of each female was determined and the data are presented in Table 4.

These data show that a differential exists between some of the strains in regard to the average number of progeny per female, for the numbers are 36 in the Persian, 37 in the Indian, 11 in the Spanish, and 6 in the Californian strain. Great differences in the maximum number of progeny per female also exist, for the top score was 99 in the Persian, 77 in the Indian, 23 in the Spanish, and 13 in the Californian *Aphytis*.

Superparasitism occurs occasionally, and the supernumerary larvae usually perish for it is seldom that more than one parasite completes its development on a single host. In very rare cases two parasites were observed to emerge from one host. This marked tendency toward solitary development occurs in all the strains studied.

A compilation of quantitative data on some of the major biological characteristics of the four *Aphytis* strains is presented in Table 5. Here it is evident that the Persian and Indian strains appear to be quite similar and a cross-mating experiment was conducted to investigate the degree of fertility in such crosses. This experiment was conducted by isolating a number of pupae of both the Persian and Indian strains singly in shell vials. On emergence the adults were sexed and four units were set up in the combinations as indicated in Table 6.

The parasites were held without access to the host scales for 24 hours to allow mating and to minimize the oviposition of unfertilized eggs during the premating period. The parasites were then permitted to oviposit and the resulting progeny were sexed to obtain the data in Table 6.

TABLE IV

Sex and number of progeny per female

Strain	Female progeny			Male progeny			Total progeny		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Persian	69	7	23	30	4	13	99	13	36
Indian	60	3	25	25	2	12	59	5	37
Spanish	23	3	11	2	0	0.1	23	3	11
Californian	13	3	6	0	0	0	13	3	6

TABLE V

Summary of biological studies on four strains of *Aphytis maculicornis*

Biological characteristic	Persian	Indian	Spanish	Californian
Total developmental period in days	16–21	15–21	19–24	20–25
Days from oviposition to peak of adult emergence	17	17	20	23
Average longevity of adults in days: A. In conditioned insectary	18	18	16	18
B. In field (April and May)	32	33	32	33
Sex ratio (percentage of females in population)	63.3	67.5	99.3	100.0
Average number of progeny per female	36	37	11	6

Although the cross-matings appeared to be less effective than the pure line breeding, the data do not indicate reproductive isolation between the cultures of the Persian and Indian strains. Soon after the strains were originally introduced in 1951 and before there was any opportunity for chance contamination of the stocks, G. L. Finney (unpublished notes) failed to get successful cross-mating with the Persian and Indian strains. Their true status thus still remains in doubt for it is possible that the two forms as originally introduced were distinct biological entities but have become accidentally mixed in the stock cultures until they can no longer be separated.

TABLE VI

Sex ratio in the progeny in a cross-mating experiment

Unit number	Crossing data	Percentage of females in the progeny
1	10 Indian ♀ x 10 Indian ♂	60.9
2	10 Persian ♀ x 10 Persian ♂	69.1
3	10 Indian ♀ x 10 Persian ♂	55.4
4	10 Persian ♀ x 10 Indian ♂	30.7

Conclusions: The data accumulated in this biological study of the *Aphytis maculicornis* complex indicate that at least three distinct sibling species exsit, namely (1) a Persian-Indian combination, (2) a Spanish type, and (3) a Californian form. The confusion between the Indian and Persian stocks justifies further study of these *Aphytis* in absolutely pure cultures. Although these sibling species are inseparable on a morphological basis they are distinctly different when viewed biologically, and the discovery of their existence serves to emphasize the importance of careful studies of imported material in quarantine and to discourage the perfunctory discarding of forms which appear to be identical with already established species.

Sibling species are inconvenient categories for the museum taxonomist, and it would seem impractical to assign names to these biological entities at this time. The value of this paper lies primarily in further alerting biological control workers to the existence of this phenomenon and encouraging the retention and study of all beneficial forms handled in quarantine units.

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(Received August 26, 1953)

Note on Occurrence of *Agathis laticinctus* (Cress.) (Hymenoptera: Braconidae) as a Parasite of the Eye-Spotted Bud Moth (Lepidoptera: Tortricidae) in Nova Scotia

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Agathis laticinctus (Cress.), a parasite of the eye-spotted bud moth, *Spilonota ocellana* (D. & S.), is of particular interest because it has only recently become the most important one attacking this pest in Nova Scotia. Sanders and Dustan (1919) found it of minor importance and Gilliatt (1932) did not find it worthy of mention. An account of its life-history has been given by Dondale (1954).

As in most research projects of the Kentville laboratory (Pickett *et al.*, 1946), attention has been given to the influence of spray practices on population densities of *A. laticinctus*.

From 1946 to 1948, shelters of the bud moth were collected and caged in large numbers from experimental and other orchards during the spring and early summer. Of 926 *A. laticinctus* adults reared from these collections, over 99 per cent came from orchards that had had little or no arsenical spray within recent years. The only insecticide-sprayed orchard that yielded large numbers of *A. laticinctus* during this time was the one experimental orchard in which DDT had been used in practically every spray, beginning in 1946.

Beginning in 1948, most of the data on the occurrence of larval parasites of the bud moth have been obtained through dissection of bud moth larvae and examination of bud moth shelters. These methods facilitate direct comparisons of the amounts of parasitism occurring in different orchards from year to year. Table1, the data in which pertain to bud moth larvae into which *A. laticinctus* had gained entry the previous summer, shows that the percentage of orchards in which no parasitism was observed declined from 46 per cent in 1948 to none in 1952, whereas the percentage in which 50-93 per cent parasitism was observed increased from 3 per cent in 1948 to 30 per cent in 1952.

There is considerable evidence that the marked increase in prevalence of *A. laticinctus* has been greatly influenced by certain widely adopted changes in spray practices during recent years. The recommendation that arsenicals be used regularly in the pre-pink and pink sprays was omitted from the official spray calendar after 1948. In 1946 a few growers had started replacing lead arsenate with DDT for codling moth control. In 1949 many growers used DDT but this practice decreased considerably in 1950 and was followed by only a few

TABLE I

Percentages of orchards in various ranges of parasitism of the eye-spotted bud moth by *A. laticinctus*, Annapolis Valley, N.S., 1948–52

Year	Number of Orchards	Percentage parasitism				
		0	1–10	11–24	25–49	50–93
1948	26	46	31	12	8	3
1949	21	33	14	10	24	19
1950	25	40	12	24	12	12
1951	45	13	11	18	25	33
1952	70	0	26	20	24	30

growers in 1951. Beginning about 1949 there was an increasing adoption of non-insecticide programs, the peak being reached in 1951.

Although there have been major changes in the fungicide program since 1945, involving the replacement of sulphur by other materials, considerable evidence from orchards receiving no insecticide and only one fungicide indicates that such changes have not caused the observed increase in parasitism by *A. laticinctus*.

The following observations indicate how spray practices may influence the amount of parasitism by *A. laticinctus*:—

1. Where arsenicals are regularly used in most sprays year after year, *A. laticinctus* is scarce or absent.

2. Where arsenicals are discontinued and replaced with a non-insecticide, a DDT, or a nicotine program, *A. laticinctus* generally appears soon after. If the parasite is already present in adjoining orchards, it may appear in moderate numbers the first year. The rate of increase following the omission of arsenicals varies greatly. The majority of the most rapid increases have occurred where the use of DDT for one or more years has been followed by the adoption of a non-insecticide program. This is apparently more favourable to *A. laticinctus* than the immediate change from an arsenical to a non-insecticide program. Parasitism of 25 to 90 per cent of the bud moth population within a year or two is not uncommon.

3. Where non-insecticide spray programs or no sprays have been used for several years, the percentage parasitism by *A. laticinctus* fluctuates about a mean of approximately 33 per cent, seldom going over 50 per cent or under 15 per cent.

4. In contrast to this, in a DDT-sprayed experimental orchard, already referred to, the percentage parasitism by *A. laticinctus* has continued at a consistently high level since 1947, ranging from 75 to 90 per cent of the *S. ocellana* population. During this time the latter have been at a very low density. The exceptionally high percentage parasitism that *A. laticinctus* attains when DDT is used probably results from the destruction of important natural enemies. Some evidence for this was observed in 1952. Examination of *A. laticinctus* cocoons in 50 orchards showed that where non-insecticide or early arsenical sprays had been used the percentage mortality within cocoons was usually high, averaging 45 and 66 per cent for 21 and 18 orchards respectively. Where DDT was used in

summer sprays in the absence of earlier arsenical sprays, mortality within cocoons was low, averaging 5 per cent for four orchards.

Though in many instances part of this mortality is due to predators and to internal and external parasites, much of it has not been accounted for, the cocoons in many cases being apparently still intact even though the *A. laticinctus* inside are dead.

Even though it is evident that DDT has a favourable influence on parasitism by *A. laticinctus*, it is not recommended for the control of the bud moth. Too many bud moths survive the DDT and too many natural enemies other than *A. laticinctus* are destroyed. During recent years, the more serious bud moth infestations in the Annapolis Valley have generally occurred in orchards in which arsenicals were replaced by DDT for one or two years to control the codling moth.

The degree of parasitism by *A. laticinctus* under orchard conditions shows no apparent relation to host density, so that if there is any tendency towards density dependence it is evidently obscured or nullified by other factors.

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(Received September 25, 1953)

Book Review

***Evolution in the Genus Drosophila* by J. T. Patterson and W. S. Stone, Professors of Zoology in the University of Texas; 610 pp., 74 text figs., 109 tables; the Macmillan Company: New York: Canadian price $8.50.**

This is a massive and comprehensive work, packed with detail on evolution in the modern sense: that is, on the changes that occur in organisms here and now and can be submitted to experimental investigation. Since the most important and extensive work in this field has been carried out in the genus Drosophila, a work which, as the authors say, presents and evaluates the more important data available from numerous sources, is extremely valuable and convenient as a work of reference.

When the problem of evolution became the subject of exact quantitative studies, the biologists investigating it rapidly lost the taste for the generalities and speculations dear to their Victorian ancestors and became involved in highly technical detailed questions. Their views on the problem of evolution as it presents itself to those interested in general or philosophical biology are often rather difficult to ascertain. This difficulty exists in the present work. The final chapter of the work, for example, does not sum up the opinion of the authors on the questions interesting to the average biologist who is not a specialist in genetics. To find these it is necessary to do a good deal of digging.

The basic view of Patterson and Stone, if I have understood them correctly, is that evolution is due, as Darwin claimed, to natural selection acting on random mutations (p. 235). They admit that the majority of mutations are detrimental at the time and place of their occurrence; nevertheless they assert that the mutations occur in such large numbers that there is ample material for constructive developments. The criticism that the mutations found in laboratory stocks of Drosophila

are the result of artificial conditions is invalidated, according to Patterson and Stone by the study of mutations present in wild strains. In this connection they quote Spencer (p. 242) who says that at certain seasons, within a few hundred yards of almost any biology laboratory in the country there occur wild or semi-wild populations of Drosophila carrying many more than the one thousand mutations reported in the text books. Such mutations, combined by natural selection are the sources of the morphologically visible differences between species. If they have been selected, that is of course because they have survival value or in other words because they are adaptive. Patterson and Stone vigorously object to the suggestion that the morphologically visible differences between species are not adaptive (p. 234). Furthermore they hold that an organism is an integrated and co-ordinated system and that a new species arises by the substitution of a number of genes so as to change one type of complex co-ordinated differentiation to another and different integrated system. The slow course of evolution they say is in part due to the fact that not only must the initial and final gene systems work but the intermediate steps must also be functional (p. 277). Nevertheless, they insist that though the majority of mutations are detrimental at the time and place of their occurrence, evolution must take place by selection among random mutations, since the only alternative to this is directed mutation to fit the needs of the organism, which is possibly only under supernatural guidance.

It has been argued, say Patterson and Stone, that the morphologically visible differences between species are *not* adaptive. The validity of this argument, they reply, is highly improbable, for there is no known genetic mechanism that would fix numerous selectively indifferent mutations on a scale sufficient to account for the many visible differences between the known species, (p. 234). However, as already noted, the authors agree that the majority of mutations are detrimental at the time and place of their occurrence. Their view therefore is that most mutations are detrimental to the organism, a small number are beneficial or have selective value but the existence of really selectively indifferent mutations is doubtful. For the existence of such mutations, they say (p. 234), there is very little if any proof.

A good many biologists find it difficult to accept the doctrine constituted by the propositions I have cited. The fundamental difficulty, which has always characterized the Darwinian doctrine, is the combination of an extreme morphological finalism with an equally extreme biological and cosmic anti-finalism. Every specific character is positively useful—has survival value—and yet the production of these characters and therefore the course of evolution is due to random action, so that they arise entirely by chance. Furthermore, it is admitted that the organism is a co-ordinated assemblage of these positively useful characters and that during the course of evolution this positive coordination must be continually maintained. However the coordination between the characters, like the characters themselves is entirely due to chance. In his little book "L'Origine des Espèces" (Paris, 1947) the Swiss geneticist Emile Guyénot, after discussing the possibility that an eye might come into existence in this way, concluded that the mutationist explanation there runs up against a real impossibility.

The Darwinian geneticists would not strain our credulity so severely if they did not insist that they can explain everything. In the Diptera there are many characteristics which seem to resemble the results of the mutations observed in Drosophila. *Striphosoma sabulosum* Hal. has reduced wings as have the mutations of *Drosophila melanogaster* known as "apterous". Cryptochaetum in the family Agromyzidae lacks an arista like the mutation "Aristaless". In a number of Tachinids, sections of the longitudinal wing veins are missing. Something of the

same sort occurs in the mutation of *melanogaster* known as "veinlet". The reduction of wings observed in some Drosophila mutants may also be compared with the condition in many Hymenoptera, for example in the species of the Ichneumonid genus Gelis containing both winged and apterous species. If we can bring ourselves to recognize that the morphological characters of organisms are in many cases not merely useless but actually disadvantageous, the idea that they may be the result of a random process becomes more acceptable. The mere fact that the Darwinians require this postulate to support their theory is hardly enough to convince an unbiased observer that the morphologically visible differences between species are often adaptive. Extremely delicate differences in the colour of the pollen and in the arrangement and number of certain bristles on the body are used to separate species of Tachinids in many genera and seem to have real systematic value. Nevertheless, to take only one example, it is impossible to imagine that the row of discal macrochaetae on the fourth segment of *Carcelia flavirostris* v.d.W. is an exact and special adaptation of the species to its mode of life while the absence of these macrochaetae on the same segment is another equally real adaptation to the mode of life in *Carcelia diacrisiae* Sell. It is hard to see what advantage a particular species of Gelis can gain from the loss of its wings. Parasites of different species or even different genera, easily distinguished morphologically, sometimes attack the same host species and live in them in the same way. What the facts indicate it seems to me, is not the strict morphological adaptation of the organism to a particular environment. It is rather that organisms can get along in the same environment with very different equipments. Sometimes the organism gets on very well with what looks like poor equipment, sometimes it gets on very poorly with equipment that is apparently excellent, just as a good carpenter can do a better job with poor tools than a bad carpenter can do with first class tools. There is of course a morphological limit below which existence becomes impossible; but as adaptation is essentially a dynamic phenomenon, existence under given conditions is compatible with great morphological differences.

Nevertheless it is true that the organism is a co-ordinated assemblage and that if the specific coordination is seriously disturbed, life becomes impossible. However the more clearly we recognize this the more difficult it becomes to accept the view that the coordination can be the result of a random process and the more difficult it is to suppose that the phenomena described by the geneticists, though adequate to explain microevolution, enable us to solve the problem of macroevolution. The origin of organic coordinations remains a mystery.

W. R. Thompson.

The Runge Press Limited, Ottawa
Mailed: Wednesday, March 10, 1954